IEC 61784-2

Edition 4.0   2019-04

INTERNATIONAL STANDARD

colour inside

**Industrial communication networks – Profiles –
Part 2: Additional fieldbus profiles for real-time networks based on
ISO/IEC/IEEE 8802-3**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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**INDUSTRIAL COMMUNICATION NETWORKS –
PROFILES –**

**Part 2: Additional fieldbus profiles for real-time
networks based on ISO/IEC/IEEE 8802-3**

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

NOTE   Combinations of protocol types are specified in IEC 61784-1 and IEC 61784-2.

International Standard IEC 61784-2 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This fourth edition cancels and replaces the third edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- update of reference from ISO/IEC 8802-3 to ISO/IEC/IEEE 8802-3;

- update of the dated references to the IEC 61158 series, to IEC 61784-1, to the IEC 61784-5 series and to IEC 61918 throughout the document;

- update of selection tables for CPF 2, CPF 3, CPF 4, CPF 8 and CPF 17;

- CPF3: update of the requirements for all conformance classes;

- CPF3: updated timing requirements for IO devices;

- CPF3: refining the added application classes;

- addition of a new Communication Profile Family – CPF 20 in Clause 21;

- addition of a new Communication Profile Family – CPF 21 in Clause 22.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
65c/943/FDIS	65c/952/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61784 series, published under the general title *Industrial communication networks – Profiles*, can be found on the IEC web site.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,

- withdrawn,

- replaced by a revised edition, or

- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document provides additional Communication Profiles (CP) to the existing Communication Profile Families (CPF) of IEC 61784-1 and additional CPFs with one or more CPs. These profiles meet the industrial automation market objective of identifying Real-Time Ethernet (RTE) communication networks coexisting with ISO/IEC/IEEE 8802-3 – commonly known as Ethernet. These RTE communication networks use provision from ISO/IEC/IEEE 8802-3 for the lower communication stack layers and additionally provide more predictable and reliable real-time data transfer and means for support of precise synchronization of automation equipment.

More specifically, these profiles help to correctly state the compliance of RTE communication networks with ISO/IEC/IEEE 8802-3, and to avoid the spreading of divergent implementations.

Adoption of Ethernet technology for industrial communication between controllers and even for communication with field devices promotes use of Internet technologies in the field area. This availability would be unacceptable if it causes the loss of features required in the field area for industrial communication automation networks, such as:

- real-time,
- synchronized actions between field devices like drives,
- efficient, frequent exchange of very small data records.

These new RTE profiles may take advantage of the improvements of Ethernet networks in terms of transmission bandwidth and network span.

Another implicit but essential requirement is that the typical Ethernet communication capabilities, as used in the office world, are fully retained, so that the software involved remains applicable.

The market is in need of several network solutions, each with different performance characteristics and functional capabilities, matching the diverse application requirements. RTE performance indicators (see Clause 5), which values will be provided with RTE devices based on communication profiles specified in this document, enable the user to match network devices with application-dependent performance requirements of an RTE network.

Subclause 5.1 specifies basic principles of performance indicators required to express RTE performance of a CP. Subclause 5.2 describes the view of application requirements. An application-dependent class could be used to find out a suitable CP. Clause 4 specifies how conformance of a device to the CPF or CP should be stated.

**INDUSTRIAL COMMUNICATION NETWORKS –
PROFILES –**

**Part 2: Additional fieldbus profiles for real-time
networks based on ISO/IEC/IEEE 8802-3**

1   Scope

This part of IEC 61784 specifies

- performance indicators supporting classification schemes for Real-Time Ethernet (RTE) requirements;
- profiles and related network components based on ISO/IEC/IEEE 8802-3, IEC 61158 series, and IEC 61784-1;
- RTE solutions that are able to run in parallel with ISO/IEC/IEEE 8802-3 based applications.

These communication profiles are called Real-Time Ethernet communication profiles.

NOTE The RTE communication profiles use ISO/IEC/IEEE 8802-3 communication networks and its related network components or IEC 61588 and may in some cases amend those standards to obtain RTE features.

2   Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE   All parts of the IEC 61158 series, as well as IEC 61784-1 and IEC 61784-2 are maintained simultaneously. Cross-references to these documents within the text therefore refer to the editions as dated in this list of normative references.

IEC 61158 (all parts), *Industrial communication networks – Fieldbus specifications*

IEC 61158-1:2019, *Industrial communication networks – Fieldbus specifications – Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series*

IEC 61158-2:2014, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-3-2:2014, *Industrial communication networks – Fieldbus specifications – Part 3-2: Data-link layer service definition – Type 2 elements*
IEC 61158-3-2:2014/AMD1:2019

IEC 61158-3-4:2019, *Industrial communication networks – Fieldbus specifications – Part 3-4: Data-link layer service definition – Type 4 elements*

IEC 61158-3-11:2007, *Industrial communication networks – Fieldbus specifications – Part 3-11: Data-link layer service definition – Type 11 elements*

IEC 61158-3-12:2019, *Industrial communication networks – Fieldbus specifications – Part 3-12: Data-link layer service definition – Type 12 elements*

IEC 61158-3-13:2014, *Industrial communication networks – Fieldbus specifications – Part 3-13: Data-link layer service definition – Type 13 elements*

IEC 61158-3-14:2014, *Industrial communication networks – Fieldbus specifications – Part 3-14: Data-link layer service definition – Type 14 elements*

IEC 61158-3-17:2007, *Industrial communication networks – Fieldbus specifications – Part 3-17: Data-link layer service definition – Type 17 elements*

IEC 61158-3-19:2019, *Industrial communication networks – Fieldbus specifications – Part 3-19: Data-link layer service definition – Type 19 elements*

IEC 61158-3-21:2019, *Industrial communication networks – Fieldbus specifications – Part 3-21: Data-link layer service definition – Type 21 elements*

IEC 61158-3-22:2014, *Industrial communication networks – Fieldbus specifications – Part 3-22: Data-link layer service definition – Type 22 elements*

IEC 61158-3-25:2019, *Industrial communication networks – Fieldbus specifications – Part 3-25: Data-link layer service definition – Type 25 elements*

IEC 61158-4-2:2019, *Industrial communication networks – Fieldbus specifications – Part 4-2: Data-link layer protocol specification – Type 2 elements*

IEC 61158-4-4:2019, *Industrial communication networks – Fieldbus specifications – Part 4-4: Data-link layer protocol specification – Type 4 elements*

IEC 61158-4-11:2014, *Industrial communication networks – Fieldbus specifications – Part 4-11: Data-link layer protocol specification – Type 11 elements*

IEC 61158-4-12:2019, *Industrial communication networks – Fieldbus specifications – Part 4-12: Data-link layer protocol specification – Type 12 elements*

IEC 61158-4-13:2014, *Industrial communication networks – Fieldbus specifications – Part 4-13: Data-link layer protocol specification – Type 13 elements*

IEC 61158-4-14:2014, *Industrial communication networks – Fieldbus specifications – Part 4-14: Data-link layer protocol specification – Type 14 elements*

IEC 61158-4-17:2007, *Industrial communication networks – Fieldbus specifications – Part 4-17: Data-link layer protocol specification – Type 17 elements*

IEC 61158-4-19:2019, *Industrial communication networks – Fieldbus specifications – Part 4-19: Data-link layer protocol specification – Type 19 elements*

IEC 61158-4-21:2019, *Industrial communication networks – Fieldbus specifications – Part 4-21: Data-link layer protocol specification – Type 21 elements*

IEC 61158-4-22:2014, *Industrial communication networks – Fieldbus specifications – Part 4-22: Data-link layer protocol specification – Type 22 elements*

IEC 61158-4-25:2019, *Industrial communication networks – Fieldbus specifications – Part 4-25: Data-link layer protocol specification – Type 25 elements*

IEC 61158-5-2:2019, *Industrial communication networks – Fieldbus specifications – Part 5-2: Application layer service definition – Type 2 elements*

IEC 61158-5-4:2019, *Industrial communication networks – Fieldbus specifications – Part 5-4: Application layer service definition – Type 4 elements*

IEC 61158-5-10:2019, *Industrial communication networks – Fieldbus specifications – Part 5-10: Application layer service definition – Type 10 elements*

IEC 61158-5-11:2007, *Industrial communication networks – Fieldbus specifications – Part 5-11: Application layer service definition – Type 11 elements*

IEC 61158-5-12:2019, *Industrial communication networks – Fieldbus specifications – Part 5-12: Application layer service definition – Type 12 elements*

IEC 61158-5-13:2014, *Industrial communication networks – Fieldbus specifications – Part 5-13: Application layer service definition – Type 13 elements*

IEC 61158-5-14:2014, *Industrial communication networks – Fieldbus specifications – Part 5-14: Application layer service definition – Type 14 elements*

IEC 61158-5-15:2010, *Industrial communication networks – Fieldbus specifications – Part 5-15: Application layer service definition – Type 15 elements*

IEC 61158-5-17:2007, *Industrial communication networks – Fieldbus specifications – Part 5-17: Application layer service definition – Type 17 elements*

IEC 61158-5-19:2019, *Industrial communication networks – Fieldbus specifications – Part 5-19: Application layer service definition – Type 19 elements*

IEC 61158-5-21:2019, *Industrial communication networks – Fieldbus specifications – Part 5-21: Application layer service definition – Type 21 elements*

IEC 61158-5-22:2014, *Industrial communication networks – Fieldbus specifications – Part 5-22: Application layer service definition – Type 22 elements*

IEC 61158-5-23:2019, *Industrial communication networks – Fieldbus specifications – Part 5-23: Application layer service definition – Type 23 elements*

IEC 61158-5-25:2019, *Industrial communication networks – Fieldbus specifications – Part 5-25: Application layer service definition – Type 25 elements*

IEC 61158-5-26:2019, *Industrial communication networks – Fieldbus specifications – Part 5-26: Application layer service definition – Type 26 elements*

IEC 61158-6-2:2019, *Industrial communication networks – Fieldbus specifications – Part 6-2: Application layer protocol specification – Type 2 elements*

IEC 61158-6-4:2019, *Industrial communication networks – Fieldbus specifications – Part 6-4: Application layer protocol specification – Type 4 elements*

IEC 61158-6-10:2019, *Industrial communication networks – Fieldbus specifications – Part 6-10: Application layer protocol specification – Type 10 elements*

IEC 61158-6-11:2007, *Industrial communication networks – Fieldbus specifications – Part 6-11: Application layer protocol specification – Type 11 elements*

IEC 61158-6-12:2019, *Industrial communication networks – Fieldbus specifications – Part 6-12: Application layer protocol specification – Type 12 elements*

IEC 61158-6-13:2014, *Industrial communication networks – Fieldbus specifications – Part 6-13: Application layer protocol specification – Type 13 elements*

IEC 61158-6-14:2014, *Industrial communication networks – Fieldbus specifications – Part 6-14: Application layer protocol specification – Type 14 elements*

IEC 61158-6-15:2010, *Industrial communication networks – Fieldbus specifications – Part 6-15: Application layer protocol specification – Type 15 elements*

IEC 61158-6-17:2007, *Industrial communication networks – Fieldbus specifications – Part 6-17: Application layer protocol specification – Type 17 elements*

IEC 61158-6-19:2019, *Industrial communication networks – Fieldbus specifications – Part 6-19: Application layer protocol specification – Type 19 elements*

IEC 61158-6-21:2019, *Industrial communication networks – Fieldbus specifications – Part 6-21: Application layer protocol specification – Type 21 elements*

IEC 61158-6-22:2014, *Industrial communication networks – Fieldbus specifications – Part 6-22: Application layer protocol specification – Type 22 elements*

IEC 61158-6-23:2019, *Industrial communication networks – Fieldbus specifications – Part 6-23: Application layer protocol specification – Type 23 elements*

IEC 61158-6-25:2019, *Industrial communication networks – Fieldbus specifications – Part 6-25: Application layer protocol specification – Type 25 elements*

IEC 61158-6-26:2019, *Industrial communication networks – Fieldbus specifications – Part 6-26: Application layer protocol specification – Type 26 elements*

IEC 61588:2009, *Precision clock synchronization protocol for networked measurement and control systems*

IEC 61784-1:2019, *Industrial communication networks – Profiles – Part 1: Fieldbus profiles*

IEC 61784-5-2:2018, *Industrial communication networks – Profiles – Part 5-2: Installation of fieldbuses – Installation profiles for CPF 2*

IEC 61784-5-3:2018, *Industrial communication networks – Profiles – Part 5-3: Installation of fieldbuses – Installation profiles for CPF 3*

IEC 61784-5-6:2018, *Industrial communication networks – Profiles – Part 5-6: Installation of fieldbuses – Installation profiles for CPF 6*

IEC 61784-5-8:2018, *Industrial communication networks – Profiles – Part 5-8: Installation of fieldbuses – Installation profiles for CPF 8*

IEC 61784-5-11:2013, *Industrial communication networks – Profiles – Part 5-11: Installation of fieldbuses – Installation profiles for CPF 11*

IEC 61784-5-21:2018, *Industrial communication networks – Profiles – Part 5-21: Installation of fieldbuses – Installation profiles for CPF 21*

IEC 61918:2018, *Industrial communication networks – Installation of communication networks in industrial premises*

IEC 61800 (all parts), *Adjustable speed electrical power drive systems*

IEC 62439-2*, Industrial communication networks – High availability automation networks – Part 2: Media Redundancy Protocol (MRP)*

ISO/IEC 7498-1, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO/IEC 8802-2, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 2: Logical link control*

ISO/IEC/IEEE 8802-3:2017, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

ISO/IEC 8802-11, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications*

ISO/IEC 9834-8, *Information technology – Procedures for the operation of object identifier registration authorities – Part 8: Generation of universally unique identifiers (UUIDs) and their use in object identifiers*

ISO/IEC 11801:2002 [1], *Information technology – Generic cabling for customer premises* [2]
ISO/IEC 11801:2002/AMD1: 2008
ISO/IEC 11801:2002/AMD 2:2010

ISO 15745-3, *Industrial automation systems and integration – Open systems application integration framework – Part 3: Reference description for IEC 61158-based control systems*

ISO 15745-4:2003, *Industrial automation systems and integration – Open systems application integration framework – Part 4: Reference description for Ethernet-based control systems*
ISO 15745-4:2003/AMD1:2006, *PROFINET profiles*

IEEE 802-2001, *IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture*

IEEE 802.1AB, *IEEE Standard for Local and metropolitan area networks – Station and Media Access Control Connectivity Discovery*

IEEE 802.1AS, *IEEE standard for Local and metropolitan area networks – Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks*

IEEE 802.1D-2004, *IEEE Standard for Local and Metropolitan Area Networks – Media access control (MAC) Bridges*

IEEE 802.1Q, *IEEE Standard for Local and metropolitan area networks – Bridges and Bridged Networks*

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[1]   Withdrawn.

[2]   There exists a consolidated edition 2.2:2011 that comprises ISO/IEC 11801:2002, its Amendment 1:2008 and its Amendment 2:2010.

IEEE Std 802.11, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks– Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*

IEEE Std 802.15.1, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.1: Wireless medium access control (MAC) and physical layer (PHY) specifications for wireless personal area networks (WPANs)*

IETF RFC 768, *User Datagram Protocol*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 791, *Internet Protocol*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 792, *Internet Control Message Protocol*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 793, *Transmission Control Protocol*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 826, *Ethernet Address Resolution Protocol*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 894, *A standard for the Transmission of IP Datagrams over Ethernet Networks*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 919, *Broadcasting Internet Datagrams*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 922, *Broadcasting Internet datagrams in the presence of subnets*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 950, *Internet Standard Subnetting Procedure*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 1034, *Domain names – Concepts and facilities*; available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 1112, *Host Extensions for IP Multicasting*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 1122, *Requirements for Internet Hosts – Communication Layers*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 1123, *Requirements for Internet Hosts – Application and Support,* available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 1127, *A Perspective on the Host Requirements RFCs*, available at <http://www.ietf.org> [viewed 2017-05-29]

IETF RFC 1157, *Simple Network Management Protocol (SNMP)*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 1213, *Management Information Base for Network Management of TCP/IP-based internets: MIB-II*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 1305, *Network Time Protocol (Version 3)*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 2131, *Dynamic Host Configuration Protocol*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 2236, *Internet Group Management Protocol, Version 2*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 2544, *Benchmarking Methodology for Network Interconnect Devices*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 2988, *Computing TCP's Retransmission Timer*, available at <http://www.ietf.org> [viewed 2018-09-03]

IETF RFC 4836, *Definitions of Managed Objects for IEEE 802.3 Medium Attachment Units (MAUs)*, available at <http://www.ietf.org> [viewed 2018-09-03]

The Open Group – Publication C706, *Technical standard DCE1.1: Remote Procedure Call*, available at <http://www.opengroup.org/onlinepubs/9629399/toc.htm> [viewed 2018-09-03]

3 Terms, definitions, abbreviated terms, acronyms, and conventions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC/IEEE 8802-3, IEEE 802, IEEE 802.1AB, IEEE 802.1AS, IEEE 802.1D, IEEE 802.1Q, and the following, apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

• IEC Electropedia: available at http://www.electropedia.org/

• ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
active network
network in which data transmission between non-immediately-connected devices is dependent on active elements within those intervening devices that form the connection path

[SOURCE: IEC 61918:2018, 3.1.3]

3.1.2
communication cycle
<CPF 16>
fixed time period between two master synchronization telegrams

3.1.3
cyclic
repetitive in a regular manner

3.1.4
domain
<CPF 10>
part of the network consisting of one or two subnetwork(s)

Note 1 to entry: Two subnetworks are required to compose a dual-redundant network, and each end-station in the domain is connected to both of the subnetworks.

3.1.5
end-station
system attached to a network that is an initial source or a final destination of MAC frames transmitted across that network

Note 1 to entry: A network layer router is, from the perspective of the network, an end-station. A switch, in its role of forwarding MAC frames from one link to another, is not an end-station.

3.1.6
field area
place in a manufacturing or process site where field devices are located

3.1.7
frame
a unit of data transmission on an ISO/IEC/IEEE 8802-3 MAC (Media Access Control) that conveys a protocol data unit (PDU) between MAC service users

[SOURCE: IEEE 802.1Q]

3.1.8
identification number
IDN
<CPF 16>
designation of operating data under which a data block is preserved with its attribute, name, unit, minimum and maximum input values, and the data

3.1.9
IP channel
<CPF 16>
defined time slot within the communication cycle, which passes ISO/IEC/IEEE 8802-3 Ethernet protocol frames (non-real-time communication)

3.1.10
jitter
temporal change in clock signal or temporal change in otherwise regular event

3.1.11
linear topology
topology where the nodes are connected in series, with two nodes each connected to only one other node and all others each connected to two other nodes (that is, connected in the shape of a line)

[SOURCE: IEC 61918:2018, 3.1.44]

3.1.12
link
transmission path between two adjacent nodes

[SOURCE: derived from ISO/IEC 11801:2002]

3.1.13
logical double line
<CPF 18>
sequence of root device and all ordinary devices processing the DLPDU in forward and backward direction

3.1.14
master
<CPF 16>
node which assigns the other nodes the right to transmit

3.1.15
message
ordered series of octets intended to convey information

Note 1 to entry: Normally used to convey information between peers at the application layer.

[SOURCE: IEC 61158-1]

3.1.16
MDT0 telegram
<CPF 16>
telegram, in which the master transmits its synchronization data, as well as parts or all of its real-time data, to the slaves

3.1.17
node
network entity connected to one or more links

Note 1 to entry: A node may be either a switch, an end-station or an RTE end-station.

3.1.18
packet
logical grouping of information used to describe a unit of data at any layer to convey the upper layer user data to its peer layer

Note 1 to entry: A packet is identical to the PDU at each layer in terms of the OSI reference model. A data-link layer packet is a frame.

3.1.19
real-time
ability of a system to provide a required result in a bounded time

3.1.20
real-time communication
transfer of data in real time

3.1.21
Real-Time Ethernet
RTE
ISO/IEC/IEEE 8802-3 based network that includes real-time communication

Note 1 to entry: Other communication can be supported, providing the real-time communication is not compromised.

Note 2 to entry: This definition is dedicated but not limited to ISO/IEC/IEEE 8802-3. It could be applicable to other IEEE 802 specifications, for example IEEE 802.11.

3.1.22
real time frame line
RTFL
<CPF 18>
communication model with devices communicating in a logical double line

3.1.23
real time frame network
RTFN
<CPF 18>
communication model with devices communicating in a switched network

3.1.24
ring
active network where each node is connected in series to two other nodes

Note 1 to entry: Ring may also be referred to as loop.

[SOURCE: IEC 61918:2018, 3.1.63, modified – The note to entry has been added]

3.1.25
router
<CPF 10>
intermediate equipment that connects two or more subnetworks using a network layer relay function

3.1.26
RTE end device
device with at least one RTE end-station

3.1.27
RTE end-station
end-station with RTE capability

3.1.28
schedule
temporal arrangement of a number of related operations

3.1.29
star
network of three or more devices where all devices are connected to a central point

[SOURCE: IEC 61918:2018, 3.1.69, modified – "which may be active or passive" has been suppressed]

3.1.30
subnetwork
<CPF 10>
part of a network that does not contain any routers

Note 1 to entry: A subnetwork consists of end-stations, bridges and segments.

Note 2 to entry: Every end-station included in a subnetwork has the same IP network address.

3.1.31
switch
MAC bridge as defined in IEEE 802.1Q

3.1.32
telegram
<CPF 16>
frame

3.2   Abbreviated terms and acronyms

AL	Application Layer
APDU	Application Protocol Data Unit
API	Application Process Identifier
AR	Application Relationship
ARP	Address Resolution Protocol
ASE	Application Service Element
CP	Communication Profile [according to IEC 61784-1]
CPF	Communication Profile Family [according to IEC 61784-1]
CRC	Cyclic Redundancy Check
CSMA-CD	Carrier Sense Multiple Access with Collision Detection
DA	Destination MAC Address
DCP	Discovery and basic Configuration Protocol (see IEC 61158-6-10)
DHCP	Dynamic Host Configuration Protocol (see IETF RFC 2131)
DL	Data-Link layer (as a prefix)
DLL	DL-Layer
DNS	Domain Name Service (see IETF RFC 1034)
DUT	Device under test
ECSME	EPA Communication Scheduling Management Entity
FA	Factory Automation
FCS	Frame check sequence
FrameID	Frame Identificator (see IEC 61158-6-10)
GSD	General station description
HW	Hardware
IANA	Internet Assigned Numbers Authority
ICMP	Internet Control Message Protocol (see IETF RFC 792)
ID	Identifier
IDN	IDentification Number
IETF	Internet Engineering Task Force
IO	Input Output
IP	Internet Protocol (see IETF RFC 791)
IPv4	Internet Protocol version 4 (see IETF RFC 791)
IRT	Isochronous RT
LAN	Local Area Network
LLC	Logical Link Control
LLDP	Link Layer Discovery Protocol (see IEEE 802.1AB)
MAC	Media Access Control
MAC	Media Access Control (see ISO/IEC/IEEE 8802-3)
Mbit/s	Million bits per second

Moctets/s	Million octets per second
MCR	Multicast communication relation
MIB	Management Information base
MRP	Medium redundancy protocol (see IEC 62439-2)
MRPD	Media redundancy for planned duplication
ms	milli seconds
n.a.	Not applicable
NoS	Number of Switches
NRT	Non-real-time
PDU	Protocol Data Unit
PI	Performance indicator
ns	nano seconds
OID	Object Identifier (see IETF RFC 1157)
PDU	Protocol Data Unit
PhL	Physical Layer
Phy	PHY Physical layer entity sublayer (see ISO/IEC/IEEE 8802-3)
PI	Performance indicator
pps	Packets per second
PTCP	Precision Transparent Clock Protocol
PTP	Precision Time Protocol [IEC 61588]
RPC	Remote Procedure Call (see The Open Group – Publication C706)
RSTP	Rapid Spanning Tree Algorithm and Protocol (see IEEE 802.1Q)
RT	Real-time
RTA	Real-time protocol acyclic
RTE	Real-time Ethernet
RT-Ethernet	Real-time Ethernet
RTFL	Real time frame line
RTFN	Real time frame network
RTO	Retransmission Time Out [according to IETF RFC 2988 – Computing TCP's Retransmission Timer]
RTPS	Real-Time Publish-Subscribe
SERCOS	SErial Real time COmmunication System
SNMP	Simple Network Management Protocol (see IETF RFC 1157)
TCC	Time-Critical Cyclic
TCP	Transmission Control Protocol (see IETF RFC 793)
TOS	Type of Service
UDP	User Datagram Protocol (see IETF RFC 768)
VLAN	Virtual LAN

3.3 Symbols

NOTE Definitions of symbols in this subclause 3.3 do not use the italic font, as they are already identified as symbols.

3.3.1 CPF 2 symbols

Symbol	Definition	Unit
APDUsize	Size of the application protocol data unit per CP 2/2 connection	octets
CD	Cable segment delay	µs
CL	Cable segment length	m
DT	Delivery time	µs
EN_NRTE_PR	End-station non-RTE packet rate per CP 2/2 connection	pps
EN_RTE_PR	End-station RTE packet rate per CP 2/2 connection	pps
EN_PR	End-station packet rate	pps
EN_PR_MAX	End-station maximum packet rate	pps
EN_TNRTE_PR	End-station total non-RTE packet rate in pps	pps
EN_TRTE_PR	End-station total RTE packet rate	pps
k	Number of CP 2/2 connections supported by the end-station	–
m	Number of CR 2/2 non-RTE connections	–
n	Number of switches between sending and receiving end-stations	–
p	Number of CR 2/2 RTE connections	–
NRTE_BW	Non-RTE bandwidth	%
PD	Cable propagation delay	n/m
SD_r	Receiver stack delay	µs
SD_s	Sender stack delay	µs
SL	Switch latency	µs
SPD	Switch processing delay	µs
T_{x_packet}	Packet transmit time	µs

3.3.2 CPF 3 symbols

Symbol	Definition	Unit
Cd	Cable delay (see attribute cable_delay in IEC 61158–5–10)	s
Clt	Total cable length	m
cta_R	Application cycle time of the Receiver	s
cta_S	Application cycle time of the Sender	s
Ctc	Communication cycle time	s
Ctc	Communication cycle time	s
Data	Complete Ethernet frame	octets
data_request	Requested RTE throughput	octets/s
data_RTE	Actual RTE throughput	octets/s
DT	Delivery time	s
endStations	Number of end-stations	—
EthernetDataRate	Ethernet data rate of the network	Mbit/s
MAC_delay	Delay on MAC layer	s
NonRTE	Percentage of non-RTE bandwidth	%
NoS	Number of switches	—
Od	Other delays, e. g. signal forwarding in a ring	s
Pd	Propagation delay	s
Phy_R_delay	PHY delay on receiver side	s
Phy_S_delay	PHY delay on sender side	s
protocolRTE	Percentage of protocol time	s
Queue_delay	Queue delay in a switch	s
RM	Time needed for management functions to support redundancy	s
RR	Attribute *Reduction Ratio* (see IEC 61158–5–10)	—
SCF	Attribute *Send Clock Factor* (see IEC 61158–5–10)	—
STTr	Receiver stack traversal time including PHY and MAC	s
STTs	Sender stack traversal time including PHY and MAC	s
Throughput_RTE	Throughput RTE	octets/s
Time_synchron_accuracy	Time synchronization accuracy	s
Tt	Transfer time	s

3.3.3   CPF 4 symbols

Symbol	Definition	Unit
cd	Cable delay (Maximum on 100 m)	μs
DT	Delivery time	μs
DTb	Delivery time, calculated by best-case values	μs
DTw	Delivery time, calculated by worst-case values	μs
FS	Number of frames allowed to be sent per second for one RTE end-station	–
NoAS	Number of accesses allowed per device per second	–
NoCEN	Number of RTE end-stations which can produce frames on the critical switch-to-switch link	–
NoNs[x]	Number of RTE end-stations connected to switch number x	–
NoNt	Number of RTE end-stations, in total	–
NoS	Number of switches in path from sender to receiver	–
pd	Propagation delay within a switch. Required minimum value	μs
QTES	Ethernet enforced quiet time on end-station to switch link	μs
QTSS	Ethernet enforced quiet time on switch-to-switch link	μs
STTr	Receiver stack transversal time including Phy and MAC	μs
STTs	Sender stack transversal time including Phy and MAC	μs
ttES	P-NET transfer time RTE end-station to switch (at maximum APDU size)	μs
ttESmin	P-NET transfer time RTE end-station to switch (at min APDU size)	μs
ttSS	P-NET transfer time switch-to-switch (at maximum APDU size)	μs

3.3.4   CPF 6 symbols

Symbol	Definition	Unit
DTLD	Total delivery time between a Type 8 slave and a Type 10 entity	μs
DT10	Delivery time of the Type 10 network	μs
Cta_M	Application cycle time of the mapping application in the linking-device	
M	Type 8 Master implementation factor	–
n	Number of data octets (user data; payload)	octets
sl8	Number of Type 8 slaves connected to the linking-device	–
T_{bit}	Nominal bit duration (see 27.2 in IEC 61158-2)	μs
t_S	Software processing time of the Type 8 master (application specific)	μs

3.3.5 CPF 10 symbols

Symbol	Definition	Unit
Cdly	Cable delay	μs
Clen	Cable length	m
Dlen	Length of the complete Ethernet frame	bit
DT	Delivery time	μs
DTlost1	Maximum delivery time with one lost frame for communication between two end-stations belonging to the same domain	μs
DTlost2	Maximum delivery time with one lost frame for communication between two end-stations belonging to different domains	μs
DTmax1	Maximum delivery time for communication between two end-stations belonging to the same domain	μs
DTmax2	Maximum delivery time for communication between two end-stations belonging to different domains	μs
NoS	Number of switches in path from sender to receiver	–
Spd	Switch delay under not congested condition	μs
STTr	Receiver stack transversal time including PhL, DLL and AP	μs
STTs	Sender stack transversal time including PhL, DLL and AP	μs
Trate	Transfer bit rate	Mbit/s

3.3.6   CPF 11 symbols

Symbol	Definition	Unit
BW_{CNT}	Bandwidth used both for the communication scheduling and the protocol overhead	%
BW_{NRT}	Bandwidth used for the non-RTE communications	%
BW_{RTE}	Bandwidth used for the RTE communications	%
cd	Cable delay	µs
cdl	Cable length total	km
ct	Cycle time	ms
data	Complete Ethernet frame	–
DT_H	Delivery time of the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC	ms
DT_L	Delivery time of the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC	ms
DT_M	Delivery time of the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC	ms
DV_{HS}	Total volume of the high-speed cyclic data	octets
DV_{LS}	Total volume of the low-speed cyclic data	octets
DV_{MS}	Total volume of the medium-speed cyclic data	octets
NoS	Number of switches	–
od	Other delays	µs
pd	Propagation delay	µs
STTs	Sender stack traversal time including Phy and MAC	µs
STTr	Receiver stack traversal time including Phy and MAC	µs
T_h	The high-speed transmission time period – the basic cycle_time (ct) of the TCC data service	ms
T_{HS}	Total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data	µs
T_l	The Low-speed transmission time period	ms
T_{LS}	Total sum of the frame transmit time, in which the TCC data frame conveys the Low-speed Cyclic data	µs
T_m	The Medium-speed transmission time period	ms
T_{MAC}	Time for the maintenance and control, in which a new end-station is solicited to join and the periodic time operation is controlled	µs
T_{MS}	Total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data	µs
T_{NRT}	Total sum of the frame transmit time, in which the frame, with the non-RTE data as a payload, is sent out of the end-station within the time period of T_h and is used for the standard Ethernet application on sporadic basis	µs
TR_{HS}	Throughput RTE of the high-speed cyclic data	Moctets/s
TR_{LS}	Throughput RTE of the low-speed cyclic data	Moctets/s
TR_{MS}	Throughput RTE of the medium-speed cyclic data	Moctets/s
TR_{RTE}	Throughput RTE, and the sum of TR_{HS}, TR_{LS} and TR_{MS}	Moctets/s
T_{RTE}	Total sum of the frame transmit time, in which the frame, with the RTE data as a payload of a fixed length, is sent out of the end-station within the time period of T_h	µs
T_{SCH}	Total sum of the frame transmit time for the transmission scheduling	µs
tt	Transfer time	µs

3.3.7   CPF 12 symbols

Symbol	Definition	Unit
l_{tc}	Total cable length	m
NoS	Number of slaves	–
Pd	Propagation delay	µs
t_{cd}	Cable delay	µs/m
t_{cpdl}	Data copy delay within a slave	µs
t_{cycle}	Cycle time	µs
t_D	Delivery time	µs
t_{data}	Time to transmit the longest real-time Ethernet frame	µs

3.3.8   CPF 13 symbols

Symbol	Definition	Unit
B_{NRTE}	Non-RTE bandwidth	%
M	Network MTU (maximum transmission unit)	octets
N	Number of RTE end-stations processed in one communication cycle	–
T_A	Time reserved for non-RTE data within one communication cycle	µs
T_C	Communication cycle time	µs
T_D	Delivery time	µs
$T_{FT,i}$	RTE frames transmission time for RTE end-station i	µs
T_{PR}	Processing time in the receiving end-station	µs
T_{PS}	Processing time in the sending end-station	µs
$T_{RD,i}$	Response delay of the RTE end-station i	µs
T_S	Communication cycle start delay	µs
$T_{SD,i}$	Sum of all delays of infrastructure components (switches, hubs, cabling) for the RTE end-station i	µs

3.3.9　CPF 14 symbols

Symbol	Definition	Unit
DT	Delivery time	µs
D_size	Data size	octets
LCable	Cable length	m
Ndata	Length of complete Ethernet frame	octets
NRTE_BW	Non-RTE bandwidth	%
NSwitch	Number of switches between end-stations	
RateofEthernet	Ethernet data rate	Mbit/s
RMData	Redundancy management data	octets
RTEData	Real-time data	octets
TApp_R	Receiver stack processing time including Phy and MAC	µs
TCable	Cable delay	µs
TD_Sw	Time delay in switch	µs
TEthernet_S	Sender traversal time through MAC and Phy based on ISO/IEC/IEEE 8802-3	µs
ThroughputRTE	RTE throughput	octets/s
TQueue_S	Sender queuing delay	µs
TSData	Time synchronization data	octets
TStack_S	Sender stack processing time	µs
TSwitch	Switch delay	µs
TTrf_S	Transfer time for one octet	µs
T_wire	Time per octet on a wire segment	µs
STT_s	Stack traversal time of the sender	µs
STT_r	Stack traversal time of the receiver	µs

3.3.10 CPF 15 symbols

Symbol	Definition	Unit
D_size	Data size	octets
DT	Delivery time	µs
DT_lf	Delivery time when a frame is lost	µs
DT_lfh	Delivery time when a frame is lost and the configuration is reliable with heartbeat	µs
DT_lfp	Delivery time when a frame is lost and the configuration is reliable periodic	µs
DT_n	Delivery time for the NACK message	µs
H	Period of the heartbeat, which is a configured parameter	µs
N_Sw	Number of switches between end-stations	–
RTO	TCP retransmission time out parameter	µs
STT_r	Stack traversal time of the receiver	µs
STT_r1	Part of the stack traversal time of the receiver that is independent of D-size	µs
STT_r2	Part of the stack traversal time of the receiver that depends linearly on D_size	µs
STT_s	Stack traversal time of the sender	µs
STT_s1	Part of the stack traversal time of the sender that is independent of D_size	µs
STT_s2	Part of the stack traversal time of the sender that depends linearly on D_size	µs
T	Period, which is a configured parameter	µs
T_wire	Time per octet on a wire segment	µs
TD_Sw	Time delay in switch	µs

3.3.11 CPF 16 symbols

Symbol	Definition	Unit
ac	Non-time based synchronization accuracy	ns
cd	Cable delay	µs/m
clt	Total cable length	m
ct	Cycle_time configured for the network segment	µs
data	Data to be transmitted in one cycle (including the complete Ethernet frame)	bit
DT	Delivery time	µs
fr	Frame runtime	µs
ma	Synchronization accuracy of the master device	µs
mct	Minimum cycle time	ms
N	Integer value	–
nf	Number of frames	–
nn	Number of nodes	–
pd	Propagation delay (signal delay) of a forwarding node	µs
sa	Synchronization accuracy of one slave device	µs
st	Separation time per frame	µs
tt	Transfer time	µs

3.3.12 CPF 17 symbols

Symbol	Definition	Unit
APDUsize	Size of the application protocol data unit in octets	octets
BW_{NRTE}	Non-RTE bandwidth, in %	%
LDR	Link data rate in bit per seconds	bps
LTC	Total cable length in meter	m
M	Number packets in the port transmit queue of node i in front on of this packet	–
N	Number of nodes between sending and receiving end-stations	–
NF_{E/S_MAX}	Maximum number of frames allowed to be sent per second for one end station	pps
$NF_{RTE/S}$	Number of frames allowed to be sent per second for one RTE end station	pps
Posize	Size of the protocol overhead in octets	octets
T_{CPD}	Cable propagation delay time in microseconds	µs
$T_{CPD/M}$	Cable propagation delay in nanoseconds per meter (depending on the characteristics of the selected cable)	ns/m
T_{DELAY}	Delivery time in microseconds	µs
T_{DELAY_MAX}	Maximum delivery time in microseconds	µs
T_{DELAY_MIN}	Minimum delivery time in microseconds	µs
Throughput_RTE	Throughput RTE	octets/s
$Throughput\_RTE_{MAX}$	Maximum throughput RTE	octets/s
T_{NLD}	Node latency delay time in microseconds	µs
T_{NLD_i}	Node latency delay time of node i in microseconds	µs
T_{NPD}	Node propagation delay time in microseconds	µs
T_{NPD_i}	Node propagation delay time of node i in microseconds	µs
T_{PKT}	Packet transmit time in microseconds	µs
T_{PKT_i}	Packet transmit time of node i in microseconds	µs
T_{RCV}	Receiver stack traversal time including Phy and MAC in microseconds	µs
T_{SND}	Sender stack traversal time including Phy and MAC in microseconds	µs
$T_{TX\_PKT\_ij}$	Packet transmit time of packet j in microseconds in the port transmit queue of node i in front on of this packet (depending on APDU size of node i)	µs
$T_{TX\_PKT\_j}$	Packet transmit time of packet j in microseconds in the port transmit queue in front on of this packet (depending on APDU size of node i)	µs

3.3.13 CPF 18 symbols

Symbol	Definition	Unit
l_B	Distance along the cable in backward direction	m
l_C	Cable length	m
l_F	Distance along the cable in forward direction	m
NoDoB	Number of devices in backward direction	–
NoDoF	Number of devices in forward direction	–
NoS	Number of switching devices	–
t_{CD}	Cable delay	ns/m
t_{cyc}	Cycle time of communication system/relation	µs
t_D	Delivery time	µs
t_{data}	Transmit time of DLPDUs	µs
t_{pd}	Propagation delay	µs
t_{STsink}	Sink stack traversal time	µs
t_{STsrc}	Source stack traversal time	µs
t_{SW}	Delay time of a switch	µs

3.3.14 CPF 20 symbols

Symbol	Description	Unit
BW	Total bandwidth	%
BW_{NRTE}	Non-RTE bandwidth	%
BW_{RTE}	RTE bandwidth	%
CD	Cable segment delay	µs
CL	Cable length	km
DL_{CY}	Delay of RTE frame on sender node	µs
DL_{NCY}	Delay of Non-RTE frame on sender node	µs
DL_R	Delay of receiver node	µs
DL_S	Delay of sender node	µs
DT	Delivery time of RTE	µs
F_N	The number of frames in the RTE	-
M	The number of nodes sending RTE frame	-
MC_{RTE}	Common memory capacity	octet
N	The number of nodes between sending and receiving end-stations	-
PD	Cable propagation delay	µs
P_{OH}	Protocol overhead	µs
q	The number packets in the port transmit queue	µs
RD_{HD}	Delay of hardware receiving process	µs
SD_{FM}	Delay of sending process by firmware	µs
SD_{HD}	Delay of sending process by hardware	µs
SD_s	Sender stack delay	µs
SD_r	Receiver stack delay	µs
SL	Switch latency	µs
SPD	Switch processing delay	µs
ST_{RTE}	Communication cycle time	ms
T_{CI}	Transmit time of control and information communication packet	µs
T_{CN}	Transmit time of ring control communication packet	µs
T_{CY}	Transmit time of cyclic communication packet	µs
TR_{RTE}	Throughput RTE	µs
T_X	Transmit time of target packet	µs
T_{X_j}	Transmit time of packet j	µs

3.3.15 CPF 21 symbols

Symbol	Definition	Unit
BW	Total bandwidth in %, and the 100 % is 100 Mbit/s	%
BWnrt	Non-RTE bandwidth	%
BW$_{rte}$	Bandwidth used for the RTE communications	%
Cpd$_i$	Signal propagation delay time on the cabling path between end-station #i and #(i+1)	µs
Clen$_i$	Cable length of a cable segment #i	m
DT	Delivery time	µs
DVct	Total volume of the cyclic-data sent out by all end-stations	Octets
NoS	Number of switches (including Hub) between sending and receiving end-stations	
STTsr$_i$	Sender and Receiver stack traversal time including Phy, MAC, IP, UDP or TCP and FAL processing time of end-station #i	µs
Tct	Sum total of the transmission time of all Cyclic-data frames by all end-stations	µs
Tctn$_i$	Total number of Cyclic-data frames sent out by end-station #i	
Tcs	Sum total of the transmission time up to the permissible count of general Ethernet frame including the general-purpose-server-command transmission	µs
Tms	Sum total of the transmission time up to the permissible count of message-data frame sporadically requested during one Tttkr time period	µs
Tnn	The total number of nodes participating in the logical ring;	
Trmt	Refresh-cycle-measurement time which is the elapsed time period from the time after obtaining the token by an end-station until the time the end-station obtains the token once again	µs
TRrte	Throughput RTE	Octets/s
Ttf	Packet frame transmission time	µs
Tsw$_j$	Sum total of switch (including Hub) latencies on the connection path between end-station #i and #i+1	µs
Ttk	Transmission time of the token frames out of all end-stations including the inter-frame space time for sending out the token frame immediately after sending out the final-cyclic-data frame	µs
Ttkif$_j$	Inter-frame space time for sending out the token frame immediately after sending out the final-cyclic-data frame by end-station #i	µs
Tttkr	Target-token-rotation time	µs

3.4 Conventions

3.4.1   Conventions common to all layers

3.4.1.1   (Sub)clause selection tables

(Sub)clause selection for all layers is defined in tables, as shown in Table 1 and Table 2. The selected base specifications are indicated just before the selection table(s). Selection is done at the highest (sub)clause level possible to define the profile selection unambiguously.

Table 1 – Layout of profile (sub)clause selection tables

Clause	Header	Presence	Constraints

Table 2 – Contents of (sub)clause selection tables

Column	Text	Meaning
Clause	<#>	(Sub)clause number of the base specifications
	Next clauses	any following clauses up to the last clause of the base specification
	Next Annexes	any following annexes up to the last annex of the base specification
Header	<text>	(Sub)clause title of the base specifications
Presence	NO	This (sub)clause is not included in the profile
	YES	This (sub)clause is fully (100 %) included in the profile in this case no further detail is given
	—	Presence is defined in the following subclauses
	Partial	Parts of this (sub)clause are included in the profile
	Optional	This (sub)clause may be additionally included in the profile
Constraints	See <#>	Constraints/remarks are defined in the given subclause, table or figure of this profile document
	—	No constraints other than given in the reference document (sub)clause, or not applicable
	<text>	The text defines the constraint directly; for longer text table footnotes or table notes may be used

If sequences of (sub)clauses do not match the profile, then the numbers are concatenated.

EXAMPLE   concatenated subclauses

3.4 – 3.7	—	NO	—

3.4.1.2   Service selection tables

If the selection of services is defined in a table, the format of Table 3 is used. The table identifies the selected services and includes service constraints, as explained in Table 4.

Table 3 – Layout of service selection tables

Service ref.	Service name	Usage	Constraint

Table 4 – Contents of service selection tables

Column	Text	Meaning
Service ref.	<#>	(Sub)clause number of the base specifications where the service is defined
	—	Not applicable
Service name	<text>	The name of the service
Usage	M	Mandatory
	O	Optional
	—	Service is never used
Constraints	See <#>	Constraints/remarks are defined in the given subclause, table or figure of this profile document
	—	No constraints other than those given in the reference document (sub)clause, or not applicable
	<text>	The text defines the constraint directly; for longer text table footnotes or table notes may be used

If selection of service parameters is defined in a table, the format of Table 5 is used. Each table identifies the selected parameters and includes parameter constraints, as explained in Table 6.

Table 5 – Layout of parameter selection tables

Parameter ref.	Parameter name	Usage	Constraint

Table 6 – Contents of parameter selection tables

Column	Text	Meaning
Parameter ref.	<#>	(Sub)clause number of the base specifications where the service is defined
	—	Not applicable
Parameter name	<text>	The name of the service parameter
Usage	M	Mandatory
	O	Optional
	—	Attribute is never present
Constraints	See <#>	Constraints/remarks are defined in the given subclause, table or figure of this profile document
	—	No constraints other than those given in the reference document (sub)clause, or not applicable
	<text>	The text defines the constraint directly; for longer text table footnotes or table notes may be used

3.4.2 Physical layer

No additional conventions are defined.

3.4.3 Data-link layer

3.4.3.1 Service profile conventions

No additional conventions are defined.

3.4.3.2   Service and parameter selections

These are described using the common conventions, see 3.4.1.2.

3.4.4   Application layer

3.4.4.1   Service profile conventions

ASE and class selection is described using (sub)clause selection tables, see 3.4.1.1. If the use of selected ASE and classes is further constrained this is specified in the profile (e.g. an optional item of the base standard is mandatory in the profile).

If the selection of class attributes is defined in a table, the format of Table 7 is used. The table identifies the selected class attributes and includes their constraints, as explained in Table 8.

Table 7 – Layout of class attribute selection tables

Attribute	Attribute Name	Usage	Constraint

Table 8 – Contents of class attribute selection tables

Column	Text	Meaning
Attribute	<#>	Attribute number of the base specification class
	—	Not applicable
Attribute Name	<text>	The name of the attribute
Usage	M	Mandatory
	O	Optional
	—	Attribute is never present
Constraints	See <#>	Constraints remarks are defined in the given subclause, table or figure of this profile document
	—	No constraints other than those given in the reference document (sub)clause, or not applicable
	<text>	The text defines the constraint directly; for longer text table footnotes or table notes may be used

3.4.4.2   Service and parameter selections

These are described using the common conventions, see 3.4.1.2.

4   Conformance to communication profiles

A statement of compliance with an RTE Communication Profile Family (CPF) Profile of this document shall be stated[3] as either

– Compliance to IEC 61784-2:201X CPF n <Type>, or

– Compliance to IEC 61784-2 (Ed.4.0) CPF n <Type>

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3   In accordance with ISO/IEC Directives

and a statement of compliance with a communication profile (CP) of this document shall be stated as either

– Compliance to IEC 61784-2:201X CP n/n <Type>, or

– Compliance to IEC 61784-2 (Ed.4.0) CP n/n <Type>

where the Type within the angle brackets < > is optional and the angle brackets are not to be included. Type could be any character string.

A conformance statement should be supported with appropriate documentation as defined in Clause 6.

5   RTE performance indicators

5.1   Basic principles of performance indicators

A network that includes real-time communication and is based on the ISO/IEC/IEEE 8802-3 standard is called a Real-time Ethernet (RTE) network. Users of RTE networks have different requirements for different applications. In order to satisfy these requirements in an optimal way, RTE communication networks complying with CPs described in this document will exhibit different performance.

Performance indicators (specified in 5.3) shall be used to specify capabilities of an RTE end device and an RTE communication network as well as to specify requirements of an application. Performance indicators will be used as a set of interaction means between the user of the RTE CP and the manufacturer of RTE CP compliant RTE end devices and network components. Subclause 5.2 specifies the application requirements view.

Performance indicators represent

a) capabilities of an RTE end-device,

b) capabilities of an RTE communication network,

c) as well as requirements of an application.

A consistent set of performance indicators (specified in 5.3) is used to represent the RTE capabilities. Some of the performance indicators are interdependent; in this case some indicator values depend on the value of others to provide a consistent set.

NOTE 1   The interdependence is due to physical or logical constraints, which are not changeable. For example it is not possible to have the indicators "Throughput RTE (which would use 90 % of the total bandwidth)" and "Throughput non-RTE (90 %)" at the same time because that would describe a transmission load of 180 %.

No general boundary values to specify RTE performance are specified for the indicators in this document, but device suppliers need to specify boundary values for a CP-based product if they claim to be compliant to this document.

Technology specific CPF subclauses specify

a) selection of performance indicators out of possible performance indicators defined in 5.3 relevant to a given CP, optionally with their individual limits or ranges,

b) interdependence between performance indicators,

c) optionally, lists with consistent performance indicators values.
    Each of the lists has one or more leading performance indicators. The leading performance indicators are preset to a fixed value (typically optimized to have the best overall performance). The other performance indicators in the list are shown with their related consistency limits,

d) optionally, a more comprehensive representation of the relation between performance indicators (Figure 1 shows an example of a graphical representation).
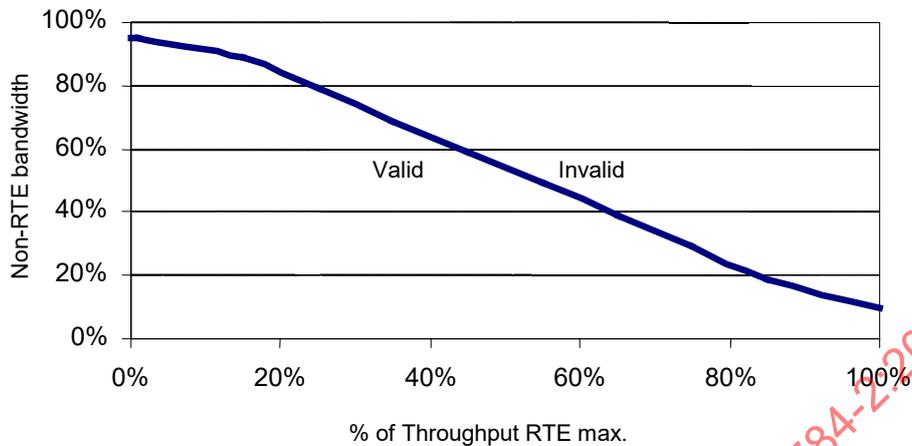
Figure 1 – Example of graphical representation of consistent indicators

The supplier of RTE end devices and RTE communication networks shall provide at least one consistent set of performance indicators. The boundary values given by the supplier should be based on conformance test principles specified in Clause 6.

NOTE 2   A set of lists with consistent performance indicators is only given when interdependence between performance indicators exists.

NOTE 3   It is possible that applications have requirements where one particular indicator has higher importance than all the others. Such applications will find useful the opportunity to select the consistent indicator list with the relevant leading indicator. Other applications may have requirements where several indicators are of equally high importance. For such applications, a graphical or otherwise more comprehensive representation of the relation between consistent indicators is more appropriate. Figure 1 is an example of a graphical representation of consistent indicators given by a CP.

NOTE 4   RTE end devices are designed under the discretion of manufactures of such a device. Therefore no assumption could be made how many RTE end-stations (network interfaces) are built in one device. In order to achieve comparable performance indicators from the application perspective, the performance indicators are built on RTE end-stations not on RTE devices.

5.2   Application requirements

The capabilities of an RTE communication network are specified in 5.3 as indicators. The indicators are used to match application requirements to the capabilities of components compliant to one or more CP(s) of this document.

A profile is suitable if its indicator values at least meet the required indicator values.

NOTE 1   Sophisticated requirements are likely to find a smaller number of matching profiles.

NOTE 2   A principle for selecting the matching CP is described in ISO 15745-1.

The application-dependent class should be a subset of a CP x/y to be suitable for this application.

5.3   Performance indicators

5.3.1   Delivery time

Delivery time shall indicate the time needed to convey an APDU containing data (message payload) that has to be delivered in real-time from one node (source) to another node

(destination). The delivery time is measured at the interface between the application process and the (Fieldbus) application entity.

NOTE 1   A description of the Application Layer concept with a description of the Application Process and the Application Entity is given in the respective type-specific part of IEC 61158-5.

The maximum delivery time shall be stated for the following two cases:

- no transmission errors, and
- one lost frame with recovery.

NOTE 2   The permanent failure condition is described in 5.3.9.

Calculation of the maximum delivery time shall include the transmission time as well as any waiting time.

NOTE 3   Waiting time depends on the RTE network concept, the RTE network topology and the application load which is generated by the other nodes in the RTE network and the non-RTE traffic at that time.

5.3.2   Number of RTE end-stations

The number of RTE end-stations shall state the maximum number of RTE end-stations supported by a CP.

NOTE   The network devices like a switch are not counted in the number of RTE end-stations.

5.3.3   Basic network topology

The basic network topology supported by a CP shall be stated out of the topologies listed in Table 9 or as a combination.

Table 9 – Basic network topology types

Basic network topology	CP
Hierarchical star	CP m/1
Ring (loop)	CP m/2
Linear topology	CP m/3
NOTE A real topology could be any combination of the three basic topologies.	

5.3.4   Number of switches between RTE end-stations

Number of switches between any two RTE end-stations that have an application relation.

5.3.5   Throughput RTE

Throughput RTE shall indicate the total amount of APDU data (by octet length) on one link per second.

5.3.6   Non-RTE bandwidth

The non-RTE bandwidth shall indicate the percentage of bandwidth, which can be used for non-RTE communication on one link. Additionally the total link bandwidth shall be specified.

NOTE   The indicators throughput RTE and non-RTE bandwidth are related to each other.

5.3.7 Time synchronization accuracy

Time synchronization accuracy shall indicate the maximum deviation between any two node clocks.

5.3.8 Non-time-based synchronization accuracy

The non-time-based synchronization accuracy shall indicate the maximum jitter of the cyclic behavior of any two nodes, using triggering by periodical events over the network for establishing cyclic behavior.

NOTE 1   This factor accounts for coherency of data or actions triggered by the event, and it is a measure of the coherency spread.

NOTE 2   The event can be unicast, multicast or broadcast, or made of a set of simpler events.

5.3.9 Redundancy recovery time

Redundancy recovery time shall indicate the maximum time from failure to become fully operational again in case of a single permanent failure.

NOTE   If a permanent failure occurs, the delivery time of a message is the redundancy recovery time.

6   Conformance tests

6.1   Concept

This document specifies the methodology of a conformance test for an RTE end device for one or more CPs. The concept of this conformance test is to verify the capabilities of a device under test (DUT) against a consistent set of indicators of a CP. The conformance test shall assure the interoperability of devices which claim compliance with the same CP. Figure 2 gives an overview of the conformance test related to this document.

NOTE   Conformance test implementation and conformance test execution are not defined in this document.
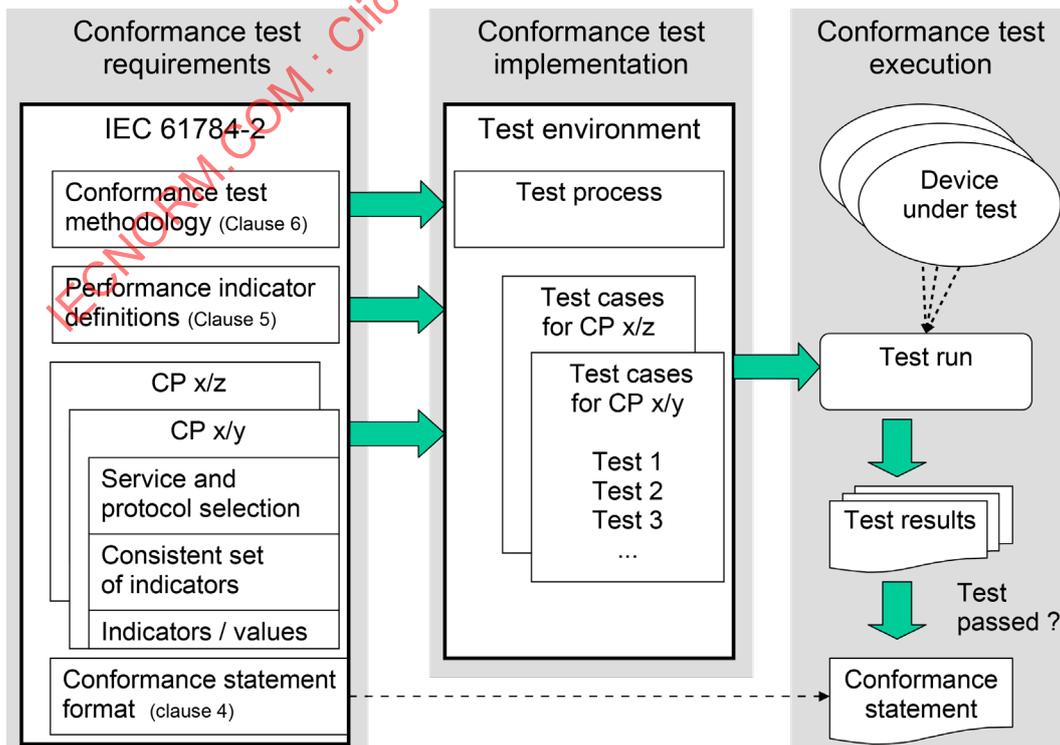
Figure 2 – Conformance test overview

6.2 Methodology

Test cases shall be developed in a way that tests are repeatable and the results can be verified. Test results shall be documented and shall be used as the basis for the conformance statement.

Conformance tests of a device shall include, as appropriate, the verification of

- the availability and correctness of the specified CP functionality,
- network related indicator values,
- device related indicator values.

The performance indicator values of the CP and of the device under test shall be used.

NOTE 1 It is assumed that the quality of the test cases guarantees the interoperability of a tested device. If any irregularities are reported the test cases will be adapted accordingly.

NOTE 2 A description of a conformance testing process is given in ISO/IEC 9646 series.

6.3 Test conditions and test cases

Test conditions and test cases shall be defined and documented based on a specific CP. This shall include the following indicators, when applicable:

- number of nodes;
- network topology;
- number of switches between nodes;
- RTE throughput;
- non-RTE bandwidth.

For each measured indicator (see 6.4), test condition and test case documents shall be prepared and shall describe:

- test purpose;
- test setup;
- test procedure;
- criteria for compliance.

Test set-up describes the equipment set-up necessary to perform the test including measurement equipment, device under test, auxiliary equipment, interconnection diagram, and test environmental conditions.

Parts of the test environment may be emulated or simulated. The effects of the emulation or simulation shall be documented.

The test procedure describes how the test should be performed, which also includes a description of specific set of indicators required to perform this test. The criteria for compliance define test results accepted as compliance with this test.

6.4 Test procedure and measuring

The measured indicators shall include, when applicable:

- delivery time;
- RTE throughput;
- non-RTE bandwidth;

- time synchronization accuracy;

- non-time based accuracy;

- redundancy recovery time.

The test procedure shall be based on the principles of 6.3.

The sequence of measuring actions to complete a test run shall be provided.

The number of independent runs of the test shall be provided.

The method to compute the result of the test from the independent runs shall be provided if applicable.

6.5   Test report

The test report shall contain sufficient information so that the test can be repeated and the results verified.

The test report shall contain at least

- the reference to the conformance test methodology according to 6.2,

- the reference to the performance indicator definitions according to Clause 5,

- the reference to the used CP according to this document,

- a description of the conformance test environment including network emulators, measurement equipment and the person or organization responsible for the test execution, and the date of testing,

- the device under test, its manufacturer, and hardware and software revision,

- the number and type of devices connected to the network together with the topology,

- a reference to the test case specifications,

- the measured values,

- a statement according compliance with the CP.

7   Communication Profile Family 2 (CIP™[4]) – RTE communication profiles

7.1   General overview

Communication Profile Family 2 defines several communication profiles based on IEC 61158-2 (protocol type 2), IEC 61158-3-2, IEC 61158-4-2, IEC 61158-5-2, and IEC 61158-6-2, and on other standards. These profiles all share for their upper layers the same communication system commonly known as the Common Industrial Protocol (CIP).

This document defines two RTE communication profiles.

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[4]   CIP™ is a trade name of ODVA, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name CIP™. Use of the trade name CIP™ requires permission from ODVA, Inc.

– Profile 2/2 EtherNet/IP™ [5]

This profile contains a selection of AL, DLL and PhL services and protocol definitions from IEC 61158-4-2, IEC 61158-5-2, and IEC 61158-6-2, and the TCP/UDP/IP/Ethernet protocol suite. This profile uses the CIP protocol and services in conjunction with the standard internet and Ethernet standards. This profile provides ISO/IEC/IEEE 8802-3:2017 based real time communication, through the use of frame prioritization.

– Profile 2/2.1 EtherNet/IP™ with time synchronization

This profile is an extension of CP 2/2 that defines additional mechanisms to provide accurate time synchronization between nodes using EtherNet/IP. The addition of time synchronization services and protocols based on IEC 61588:2009 allows using it also for the most demanding applications.

NOTE 1   See IEC 61784-1, Clause A.2, for an overview of CIP and related networks communications concepts.

NOTE 2   Additional CPs are defined in the other parts of the IEC 61784 series.

7.2   Profile 2/2

7.2.1   Physical layer

See IEC 61784-1, 6.3.1.

7.2.2   Data-link layer

See IEC 61784-1, 6.3.2.

7.2.3   Application layer

See IEC 61784-1, 6.3.3.

7.2.4   Performance indicator selection

7.2.4.1   Performance indicator overview

Table 10 provides an overview of CP 2/2 performance indicators.

Table 10 – CP 2/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	Yes	None
Number of end-stations	Yes	None
Basic network topology	Yes	Only star topology is supported
Number of switches between end-stations	Yes	None
Throughput RTE	Yes	None
Non-RTE bandwidth	Yes	None
Time synchronization accuracy	No	–
Non-time-based synchronization accuracy	No	–
Redundancy recovery time	No	–

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[5]   EtherNet/IP™ is a trade name of ODVA, Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name EtherNet/IP™. Use of the trade name EtherNet/IP™ requires permission from ODVA, Inc.

7.2.4.2   Performance indicator dependencies

7.2.4.2.1   Dependency matrix

Table 11 shows the dependencies between performance indicators for CP 2/2.

Table 11 – CP 2/2: PI dependency matrix

Dependent PI	Influencing PI					
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth
Delivery time		NO	NO	YES	NO	NO
Number of end-stations	NO		YES	YES	NO	NO
Basic network topology	NO	NO		NO	NO	NO
Number of switches between end-stations	YES	YES	YES		NO	NO
Throughput RTE	NO	NO	NO	NO		YES
Non-RTE bandwidth	NO	NO	NO	NO	YES	

7.2.4.2.2   Delivery time

Payload delivery time between any two end-stations depends on many factors as shown below. For one direction of a CP 2/2 network operating in full-duplex mode, it can be calculated for each type of application message using Formulae (1), (2) and (3).

$$DT = SD_s + T_{x\_packet} + \sum_{i=1}^{n-1} CD_i + \sum_{k=1}^{n} SL_k + SD_r \tag{1}$$

$$CD_i = PD_i \times CL_i \tag{2}$$

$$SL_k = SPD_k + \sum_{j=1}^{q} T_{x\_packet\_j} + T_{x\_packet} \tag{3}$$

where

DT	is the delivery time in microseconds;
SD_s	is the sender stack delay in microseconds (depending on the selected hardware platform and the embedded software implementation);
T_{x_packet}	is the packet transmit time in microseconds;
n	is the number of switches between sending and receiving end-stations;
CD	is the cable segment delay in microseconds;
PD	is the cable propagation delay in nanoseconds per meter (depending on the characteristics of the selected cable);
CL	is the cable segment length in meters;
SL	is the switch latency in microseconds (measured based on RFC 2544, usually provided by the switch vendor);

SPD	is the switch processing delay in microseconds (provided by the switch vendor instead of SL);
q	is the number packets in the port transmit queue in front on of this packet;
$T_{x\_packet\_j}$	is the transmit time of packet j;
SD_r	is the receiver stack delay in microseconds (depending on the selected hardware platform the and embedded software implementation).

NOTE   If a packet is lost, e.g. due to a transmission error, but the following one is received without errors then the delivery time will double. The CP 2/2 system performance will not be affected unless four consecutive packets are lost.

7.2.4.2.3   Number of end-stations

With regard to star topology, this document considers network infrastructures containing only data-link layer (Ethernet) switches. This assumes that all end-stations are connected to the same subnet. Based on the CP 2/2 specification, a subnet can contain a maximum of 1 024 end-stations. The minimum number of end-stations is two, one producer and one consumer of the RTE data.

7.2.4.2.4   Basic network topology

The basic topology of the CP 2/2 network is a hierarchical star. Since basic network topology is given, it is not dependent on, or influenced by, any of the performance indicators.

7.2.4.2.5   Number of switches between end-stations

The number of switches between end-stations, which is the number of layers in a hierarchical star, is determined on the basis of:

– delivery time;

– number of end-stations, their physical location and the distance between them;

– network traffic profile (types of traffic, rates, traffic mix);

– performance of selected switches, in particular their throughput, their physical location, distance between them and number of ports per switch;

– network management requirements.

The minimum number is 1. The maximum number is 1 024 where each end-station has an individual switch, which is similar to the linear topology.

7.2.4.2.6   Throughput RTE

In switched Ethernet networks based on the star topology a link is a link between an end-station and a switch port. Based on the definition provided in 5.3.5, throughput RTE depends on the link data rate, link mode of operation (half or full-duplex) and protocol overhead. Throughput RTE for one direction of a CP 2/2 link operating in a full-duplex mode can be calculated on the basis of Formula (4).

$$Throughput\_RTE = \sum_{i=1}^{k}(APDUsize_i \times EN\_RTE\_PR_i) \le EN\_PR\_MAX \tag{4}$$

where

APDUsize	is the size of the application protocol data unit per CP 2/2 connection in octets;
EN_RTE_PR	is the end-station RTE packet rate per CP 2/2 connection in packets per second (pps);
k	is the number of CP 2/2 connections supported by the end-station;
EN_PR_MAX	is the end-station maximum packet rate in pps.

7.2.4.2.7 Non-RTE bandwidth

CP 2/2 does not specify a percentage of bandwidth which can be used for non-RTE communication but it can be calculated as shown below.

7.2.4.2.8 Relation between throughput RTE and non-RTE bandwidth

A link in the CP 2/2 is a link between an end-station and a switch port. The total link bandwidth is limited by the end-station throughput, which is the same as the end-station maximum packet rate. The total link bandwidth is therefore a sum of end-station RTE and non-RTE packet rates and can be calculated using Formulae (5), (6), (7), (8) and (9).

$$Total\_Link\_Bandwidth = EN\_PR\_MAX \tag{5}$$

$$EN\_PR = EN\_TRTE\_PR + EN\_TNRTE\_PR \leq EN\_PR\_MAX \tag{6}$$

$$EN\_TRTE\_PR = \sum_{i=1}^{p} EN\_RTE\_PR_i \tag{7}$$

$$EN\_TNRTE\_PR = \sum_{j=1}^{m} EN\_NRTE\_PR_j \tag{8}$$

$$NRTE\_BW = \frac{EN\_PR\_MAX - EN\_TRTE\_PR}{EN\_PR\_MAX} \times 100\% \tag{9}$$

where

EN_PR	is the end-station packet rate in packets per second (pps);
EN_PR_MAX	is the end-station maximum packet rate in pps;
EN_TRTE_PR	is the end-station total RTE packet rate in pps;
EN_RTE_PR	is the end-station RTE packet rate per CP 2/2 connection in pps;
p	is the number of CR 2/2 RTE connections;
EN_TNRTE_PR	is the end-station total non-RTE packet rate in pps;
EN_NRTE_PR	is the end-station non-RTE packet rate per CP 2/2 connection in pps;
m	is the number of CR 2/2 non-RTE connections;
NRTE_BW	is the non-RTE bandwidth, in %.

EXAMPLE

End device maximum packet rate is 2 000 pps. It has 5 RTE connections, 2 with EN_RTE_PR = 200 pps and 3 with EN_RTE_PR = 100 pps. It also has 4 non-RTE connections, all with EN_NRTE_PR = 10 pps.

$$EN\_TRTE\_PR = 2 \times 200\,pps + 3 \times 100\,pps = 700\,pps$$

$$EN\_PR = 700\,pps + 40\,pps = 740\,pps$$

$$NRTE\_BW = \frac{40\,pps}{2000\,pps} \times 100\% = 2\%$$

$$NRTE\_BW_{max} = \frac{2000\,pps - 700\,pps}{2000\,pps} \times 100\% = 65\%$$

In this example, 65 % of link bandwidth can be used for non-RTE traffic but only 2 % has actually been used.

7.2.4.3 Consistent set of performance indicators

Table 12 defines a consistent set of performance indicators for CP 2/2. Minimum and maximum values of delivery time are calculated in A.1.1.1. The maximum value of the throughput RTE is calculated in A.1.1.2.

Table 12 – CP 2/2: Consistent set of PIs for factory automation

Performance indicator	Value	Constraints
Delivery time	130 µs to 20,4 ms	–
Number of end-stations	2 to 1 024	–
Number of switches between end-stations	1 to 1 024	–
Throughput RTE	0 octets/s to 3,44 x 10^6 octets/s	–
Non-RTE bandwidth	0 % to 100 %	–

7.3 Profile 2/2.1

7.3.1 Physical layer

The physical layer of the Ethernet/IP CP 2/2.1 profile is according to ISO/IEC/IEEE 8802-3:2017.

Recommended connectors and cables are specified in IEC 61918 and IEC 61784-5-2.

NOTE 1 EtherNet/IP can be used with a number of media options (e.g. copper, fiber, fiber ring, wireless) in conjunction with the Ethernet lower layers.

NOTE 2 Additional information is provided in ODVA: THE CIP NETWORKS LIBRARY – Volume 2: EtherNet/IP™ Adaptation of CIP, Chapter 8: Physical Layer.

The time stamping feature for time synchronization is implemented using a hardware assist circuit as specified in IEC 61588:2009.

7.3.2 Data-link layer

7.3.2.1 DLL service selection

The data-link layer of the CP 2/2.1 profile is according to ISO/IEC/IEEE 8802-3:2017.

7.3.2.2 DLL protocol selection

The data-link layer of the CP 2/2.1 profile is according to ISO/IEC/IEEE 8802-3:2017.

Table 13 specifies the DLL protocol selection within IEC 61158-4-2.

Table 13 – CP 2/2.1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations and conventions	YES	–
4 – 5	–	NO	–
6	Specific DLPDU structure, encoding and procedures	–	–
6.1	Modeling language	YES	–
6.2 – 6.15	–	NO	–
7	Objects for station management	–	See Table 14
8 – 9	–	NO	–
10	Device Level Ring (DLR) protocol	YES	Optional
11	PRP and HSR redundancy protocols	YES	Optional
Annex A	(normative) – Indicators and switches	–	–
A.1	Purpose	YES	–
A.2	Indicators	–	–
A.2.1	General indicator requirements	YES	–
A.2.2	Common indicator requirements	YES	–
A.2.3	Fieldbus specific indicator requirements (1)	NO	–
A.2.4	Fieldbus specific indicator requirements (2)	YES	–
A.2.5	Fieldbus specific indicator requirements (3)	NO	–
A.3	Switches	–	–
A.3.1	Common switch requirements	YES	–
A.3.2	Fieldbus specific switch requirements (1)	NO	–
A.3.3	Fieldbus specific switch requirements (2)	YES	–
A.3.4	Fieldbus specific switch requirements (3)	NO	–

Table 14 specifies the management objects selection.

Table 14 – CP 2/2.1: DLL protocol selection of management objects

Clause	Header	Presence	Constraints
7	Objects for station management	–	–
7.1	General	Partial	Relevant objects and features only
7.2	ControlNet object	NO	–
7.3	Keeper object	NO	–
7.4	Scheduling object	NO	–
7.5	TCP/IP interface object	YES	–
7.6	Ethernet link object	YES	–
7.7	DeviceNet object	NO	–
7.8	Connection configuration object	YES	–
7.9	DLR object	YES	Optional (required if DLR protocol is implemented)
7.10	QoS object	YES	Optional

Clause	Header	Presence	Constraints
7.11	Port object	YES	–
7.12	PRP/HSR Protocol object	YES	Optional (required if PRP/HSR protocol is implemented)
7.13	PRP/HSR Nodes Table object	YES	Optional (required if PRP/HSR protocol is implemented)

7.3.3   Application layer

7.3.3.1   AL service selection

Table 15 specifies the AL service selection within IEC 61158-5-2.

Table 15 – CP 2/2.1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations and conventions	YES	–
4	Common concepts	Partial	Differences are indicated in IEC 61158-5-2, 6.1
5	Data type ASE	Partial	Selection and restrictions are specified in IEC 61158-5-2, 6.1
6	Communication model specification	–	–
6.1	Concepts	YES	–
6.2	ASEs	–	–
6.2.1	Object management ASE	–	–
6.2.1.1	Overview	YES	–
6.2.1.2	FAL management model class specification	–	–
6.2.1.2.1	General formal model	YES	–
6.2.1.2.2	Identity formal model	YES	–
6.2.1.2.3	Assembly formal model	YES	–
6.2.1.2.4	Message Router formal model	YES	–
6.2.1.2.5	Acknowledge Handler formal model	YES	–
6.2.1.2.6	Time Sync formal model	YES	–
6.2.1.2.7	Parameter formal model	YES	–
6.2.1.3	FAL management model ASE service specification	YES	–
6.2.2	Connection manager ASE	YES	Single class in this ASE
6.2.3	Connection ASE	YES	Optional (internal or external)
6.3	AR's	–	–
6.3.1	Overview	YES	–
6.3.2	UCMM AR formal model	NO	–
6.3.3	Transport AR formal model	YES	–
6.3.4	AR ASE services	YES	–
6.4	Summary of FAL classes	YES	–
6.5	Permitted FAL services by AR type	YES	–

In addition AL services are mapped onto the TCP/UDP/IP protocol suite.

The corresponding minimum requirements for EtherNet/IP devices are as specified in RFC 1122, RFC 1123, RFC 1127 and subsequent documents that may supersede them. All EtherNet/IP devices shall as a minimum support requirements specified in RFC 768, RFC 791, RFC 792, RFC 793, RFC 826, RFC 894, RFC 1112 and RFC 2236.

If a feature or internet protocol is implemented by an EtherNet/IP device, this feature shall be implemented in accordance with the appropriate RFC documents, whether the feature or protocol is considered required or optional by this RFC document.

7.3.3.2   AL protocol selection

Table 16 specifies the AL protocol selection within IEC 61158-6-2.

Table 16 – CP 2/2.1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Terms, definitions, symbols, abbreviations and conventions	YES	–
4	Abstract syntax	–	–
4.1	FAL PDU abstract syntax	–	–
4.1.1 – 4.1.2	–	YES	–
4.1.3	UCMM_PDUs	NO	–
4.1.4	Transport_Headers	YES	–
4.1.5	CM_PDUs	Partial	Except 4.1.5.6.6
4.1.6 – 4.1.11	–	YES	–
4.2	Data abstract syntax specification	YES	–
4.3	Encapsulation abstract syntax	YES	–
5	Transfer syntax	YES	–
6	Structure of FAL protocol state machines	YES	–
7	AP-Context state machine	YES	–
8	FAL service protocol machine (FSPM)	YES	–
9	Application relationship protocol machines (ARPMs)	–	–
9.1	General	YES	–
9.2	Connection-less ARPM (UCMM)	–	–
9.2.1	General	YES	–
9.2.2 – 9.2.6	–	NO	–
9.3	Connection-oriented ARPMs (transports)	YES	–
10	DLL mapping protocol machine 1 (DMPM 1)	NO	–
11	DLL mapping protocol machine 2 (DMPM 2)	YES	–
12	DLL mapping protocol machine 3 (DMPM 3)	NO	–

In addition, the AL protocol is mapped onto the TCP/UDP/IP protocol suite.

The corresponding minimum requirements for EtherNet/IP devices are as specified in RFC 1122, RFC 1123, RFC 1127 and subsequent documents that may supersede them. All EtherNet/IP devices shall as a minimum support requirements specified in RFC 768, RFC 791, RFC 792, RFC 793, RFC 826, RFC 894, RFC 1112 and RFC 2236.

If a feature or internet protocol is implemented by an EtherNet/IP device, this feature shall be implemented in accordance with the appropriate RFC documents, whether the feature or protocol is considered required or optional by this RFC document.

The time synchronization protocol is implemented as specified in IEC 61588:2009.

7.3.4 Performance indicator selection

7.3.4.1 Performance indicator overview

Table 17 provides an overview of CP 2/2.1 performance indicators.

Table 17 – CP 2/2.1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	Yes	None
Number of end-stations	Yes	None
Basic network topology	Yes	Only star topology is detailed in this document
Number of switches between end-stations	Yes	None
Throughput RTE	Yes	None
Non-RTE bandwidth	Yes	None
Time synchronization accuracy	Yes	Requires switches capable to function as IEC 61588:2009 transparent clocks or boundary clocks, depending on application.
Non-time-based synchronization accuracy	No	–
Redundancy recovery time	No	–

7.3.4.2 Performance indicator dependencies

7.3.4.2.1 Dependency matrix

Table 18 shows the dependencies between performance indicators for CP 2/2.1.

Table 18 – CP 2/2.1: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time sync accuracy
Delivery time		NO	NO	YES	NO	NO	NO
Number of end-stations	NO		YES	YES	NO	NO	YES
Basic network topology	NO	NO		NO	NO	NO	NO
Number of switches between end-stations	YES	YES	YES		NO	NO	YES
Throughput RTE	NO	NO	NO	NO		YES	NO
Non-RTE bandwidth	NO	NO	NO	NO	YES		NO
Time synchronization accuracy	NO	NO	YES	YES	NO	NO	

7.3.4.2.2   Time synchronization accuracy

Accuracy of time synchronization is the maximum jitter between master and slave clocks. In order to achieve 1 μs accuracy in a star network, it is necessary to use switches containing IEC 61588:2009 boundary clocks. It has been proven that in this case the number of cascaded switches shall not exceed four (4), assuming that the accuracy of the switch boundary clock is within the range of ± 100 ns.

7.3.4.3   Consistent set of performance indicators

Table 19 defines a consistent set of performance indicators for CP 2/2.1. Minimum and maximum values of delivery time are calculated in A.1.2.1. The maximum of nodes is calculated in A.1.2.2. The maximum value of the throughput RTE is calculated in A.1.1.2.

Table 19 – CP 2/2.1: Consistent set of PIs for motion control

Performance indicator	Value	Constraints
Delivery time	130 μs to 190 μs	–
Number of end-stations	2 to 90	Maximum number of ports in switches with IEC 61588:2009 support
Number of switches between end-stations	1 to 4	Maximum number of cascaded switches with IEC 61588:2009 support
Throughput RTE	0 octets/s to 3,44 x 10^6 octets/s	–
Non-RTE bandwidth	0 % to 100 %	–
Time synchronization accuracy	≤ 1 μs	–

8 Communication Profile Family 3 (PROFIBUS & PROFINET6) – RTE communication profiles

8.1 General overview

8.1.1 CPF 3 overview

Communication Profile Family 3 (CPF 3) defines communication profiles using Type 3 and Type 10 of IEC 61158 series, which corresponds to parts of the communication systems commonly known as PROFIBUS and PROFINET. For PROFIBUS, CP 3/1 and CP 3/2 are specified in IEC 61784-1.

RTE specific PROFINET profiles are specified for three conformance classes named A, B, and C. Compliance to a CP out of the CPF 3 is a prerequisite to conform to a conformance class (see Table 86). Those conformance classes require features out of the general classifications given in 8.1.3, 8.1.4, 8.1.5, 8.1.6, 8.1.7, 8.1.8, 8.1.9, 8.1.10, and 8.1.11.

8.1.2 Administrative numbers

The administrative numbers shown in IEC 61158–6–10 shall be assigned by the authority shown in Table 20.

Table 20 – Administrative numbers assignment

Parameter	Assigning authority
API application process identifier	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, See IEC 61158–6–10, Coding of the field API
vendor ID	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, See IEC 61158–6–10, Coding of fields related to Instance, DeviceID, VendorID
enterprise number	IANA to PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, See IEC 61158–6–10, Enterprise number for PNO MIB
PNO MIB	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, See IEC 61158–6–10, Enterprise number for PNO MIB
index	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, See IEC 61158–6–10, Coding of the field Index
IM_Profile_ID	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, (See Profile ID) See IEC 61158–6–10, Coding of the field IM_Profile_ID
ChannelErrorType	PROFIBUS & PROFINET International (PI) See IEC 61158–5–10, See IEC 61158–6–10, Coding of the field ChannelErrorType

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6 PROFIBUS and PROFINET are trade names of the non-profit organization PROFIBUS Nutzerorganisation e.V. (PNO). This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade names holder or any of its products. Compliance to this profile does not require use of the registered trade name. Use of the trade names requires permission of the trade name holder.

8.1.3   Node Classes

8.1.3.1   General

Node classes are:

- IO device, with or without an integrated network component;
- IO controller, with or without an integrated network component;
- IO supervisor, and
- Network components (e.g. switch, wireless access point, wireless client).

NOTE   A node can have several node classes implemented at the same time, e.g. IO controller and IO device, IO device and integrated network component.

8.1.3.2   IO device

8.1.3.2.1   Communication

An IO device shall support at least one AR with two IO CRs, one Alarm CR, and one Record Data CR with the following features:

- IO CR:
  Maximum C_SDU data length 1 440 octets
  Minimum C_SDU data length 40 octets
  Usable C_SDU data length according to the GSD

NOTE 1   C_SDU is derived from IEC 61158–6–10.

- Alarm CR:
  Maximum RTA-SDU data length 1 432 octets
  Minimum RTA-SDU data length 200 octets

NOTE 2   RTA-SDU is derived from IEC 61158-6-10.

- Record data CR:
  Up to $2^{32} - 65$ octet data length, minimal 4 132 octets data length (length of the *PROFINETIOServiceReqPDU* or *PROFINETIOServiceResPDU*)

NOTE 3   PROFINETIOServiceReqPDU and PROFINETIOServiceResPDU are derived from IEC 61158–6–10.

8.1.3.2.2   Application

8.1.3.2.2.1   Diagnosis

An IO device shall limit the diagnosis added to the Diagnosis ASE for one submodule according to Table 21.

Table 21 – Maximum diagnosis data for one submodule

Parameter	Value	Comment
Maximum amount of diagnosis data for one submodule	< 65 536 octets	The application of a device shall limit the amount of diagnosis data which it adds to the Diagnosis ASE to a given limit. Thus a controller or an engineering could in all case get the existing diagnosis data from the Diagnosis ASE.

8.1.3.2.2.2   Persistence

An IO device shall store the parameterization or communication data according to Table 22.

Table 22 – Maximum storage delay

Service	Timeout	Comment
Startup parameterization during connection establishment, plugging of a submodule or dynamic reconfiguration	Recommended: < 30 s Mandatory: < 300 s	Timeout starts when the Appl_Rdy.req is issued by the IO device.
Record Write outside startup parametrization	Recommended: < 30 s Mandatory: < 300 s	Timeout starts when the RM_Write.rsp is issued by the responder.
SNMP Set to writeable OIDs	Recommended: < 30 s Mandatory: < 300 s	Timeout starts when the SNMP_Set.cnf is issued by the responder.
Set_Storage_Time [a]	Mandatory: < 30 s	Maximum time between the DCP_Set.rsp and the completion of persistent storage.
[a] See IEC 61158–6–10; valid for IO controller, too.		

8.1.3.2.2.3   Reporting system

An IO device shall locally store reporting system observer events according to Table 23 and Table 24. The needed storage capacity depends on the RSO event creation frequency.

Table 25 shows the expected times for switching the used timescales.

Table 23 – Reporting system minimum storage size

Minimum storage size	Comment
4 096 Octets	Minimum storage size of the reporting system

Table 24 – Reporting system storage

Frequency	Number of storable RSO events	Comment
1 s: 100 s pulse to pause ratio with a burst of 500 RSO events during pulse.	550	For a period of 101 s, under normal working conditions, no more than 500 RSO events are expected.
1 s: 100 s pulse to pause ratio with a burst of 100 RSO events during pulse.	110	For a period of 101 s, under normal working conditions, no more than 100 RSO events are expected.
1 s: 100 s pulse to pause ratio with a burst of 50 RSO events during pulse.	55	For a period of 101 s, under normal working conditions, no more than 50 RSO events are expected.

Table 25 – Reporting system Timeouts

Time Source	Time	Comment
Switch from "0" to "1"	When detecting "Time mismatch"	The connection to the sync master is lost
Switch from "1" to "2"	Recommended: < 60 s Mandatory: < 300 s	The expected deviation between the global timescale and derived global timescale at the sync slave is no longer given. Thus, the sync slave shall switch to arbitrary timescale.

8.1.3.3   IO controller

An IO controller shall support at least one AR for each related IO device including two IO CRs, one Alarm CR, and one Record Data CR with the following features:

- IO CR:
  Up to 1 440 octets C_SDU data length, min. 240 octets consistency, support of all defined data types

- Alarm CR:
  Up to 1 432 octets data length, minimal 200 octets data length, capability to queue at least one high prior and one low prior alarm for each related IO device

- Record data CR:
  Up to 2^{32}-65 octets data length, minimal 16 588 octets (recommended 66 412 octets) data length (length of the *PROFINETIOServiceReqPDU or PROFINETIOServiceResPDU*), capability to store for each related IO device at least 16 384 octets startup parameter, no parallel access to a record data object

  – WriteMultiple:
    Shall be supported for startup parameterization during Connect, Plug and dynamic reconfiguration

- Multi-API:
  At least two supported (API = 0 and API = x)

- Connect response:
  At least an ARVendorBlockRes size of 512 octets for each used ARVendorBlockReq at the connect request

NOTE   ARVendorBlockReq and ARVendorBlockRes are derived from IEC 61158–6–10.

8.1.4   Protocol and timing parameters

8.1.4.1   Internet protocol and Dynamic name service

The recommended values for the IP layer defined in IETF RFC 791 are shown in Table 26 and Table 27.

Table 26 – IP layer parameters for IO controller

Parameter	Value	Comment
ARP_Cache_Size	Minimum 32	The amount of the supported IODs
ARP_Cache_Timeout	60 s	—

Table 27 – IP layer parameters for IO device

Parameter	Value	Comment
ARP_Cache_Size	Minimum 32	—
ARP_Cache_Timeout	60 s	—

The allowed time values for name resolution defined in IEC 61158–6–10, 4.12 are shown in Table 28.

Table 28 – Timeout values for name resolution

Parameter	Value	Comment
ARP-ResponseTimeout	2 s	See IETF RFC 826
DCP-IdentifyTimeout	≥ 400 ms	See IEC 61158–6–10, 4.3.2
DCP-Set/GetTimeout	1 s	See IEC 61158–6–10, 4.3.2
DCP MaxRetryLimit Set/Get	2	See IEC 61158–6–10, 4.3.2
DNS-RequestTimeout	16 s	See IETF RFC 1034

8.1.4.2 IO device

Table 29 contains limitations for AL timing parameters of an IO device.

Table 29 – Reaction time for an IO device

Parameter	Meaning	Value
MinDeviceInterval [a]	This performance parameter is an IO device property and part of the device description.	≤ 128 ms for CP 3/4 and CP 3/5 ≤ 1 ms for CP 3/6
MinDeviceIntervalUDP	This performance parameter is an IO device property.	≤ 4 000 ms for RT_CLASS_UDP
Remote_Application_Timeout [b]	The parameter Remote_Application_Timeout represents the deadline of a RPC call.	≤ 300 s
Remote_Application_Ready_Timeout [c]	The parameter Remote_Application_Ready_Timeout represents the deadline between IODControlRes (ControlCommand.PrmEnd) and IOXControlReq (ControlCommand.Application-Ready).	≤ 300 s
AR_Resource_Release_Timeout	The parameter AR_Ressource_Release_Timeout represents the deadline between IODReleaseRes and IODConnectReq.	≤ 100 ms recommended ≤ 1 s mandatory
Set_Usage_Time [c]	Maximum time between the DCP_Set.rsp and the usage of the set values in all affected protocols. For the IP suite see IP_Startup_Time.	≤ 400 ms mandatory
IP_Startup_Time [c]	Time between the DCP_Set.rsp and the accessibility of the IP layer with ARP [d] or the PROFINETIOServiceReqPDU.	≤ 30 s recommended ≤ 300 s mandatory
Reset_to_Factory_Time [c]	Time between the DCP_Set.rsp and the deletion of the name of station and the IP parameter.	≤ 30 s recommended ≤ 300 s mandatory
Autonegotiation timeout [e]	Time between the connection is established/detected and the communication parameters for the link are active.	≤ 3 s recommended ≤ 30 s mandatory

[a] See ISO 15745–4/Amd1

[b] See The Open Group – Publication C706

[c] See IEC 61158–6–10;
If supported, value valid for IO controller, too.

[d] See IETF RFC 826

[e] See ISO/IEC/IEEE 8802-3

An IO device shall support at least one ReductionRatio SendClockFactor combination, which fulfills Formula (10)

$$MinDeviceInterval = RR \times SCF \times 31,25\ \mu s \qquad (10)$$

$$RR = \frac{MinDeviceInterval}{SCF \times 31,25\mu s}$$

where

MinDeviceInterval	is the achieved communication interval;
SCF	is the attribute *SendClockFactor* (see IEC 61158–5–10, Send Clock Factor);
RR	is the attribute *ReductionRatio* (see IEC 61158–5–10, Reduction Ratio).
31,25 µs	is the basic clock rate.

NOTE 1   Each IO device implementation has to ensure that the MinDeviceInterval and Remote_Application_Timeout reach the smallest possible value.

NOTE 2   The supported SCF in conjunction with the MinDeviceInterval limits the supported RR of a device.

NOTE 3   The GSD of a device defines the supported ReductionRatios and SendClockFactors.

8.1.4.3   Media redundancy protocol

The allowed values for MRP defined in IEC 61158–6–10 are shown in Table 30 and Table 31.

Table 30 – Maximum time values for MRP

Parameter	Value	Comment
Max Bridge Delay [a, b]	≤ 4 ms	Every bridge supporting MRP shall forward a MRP-PDU in this time.
[a] For forwarding MRP Test Frames		
[b] A lesser BridgeDelay allows a greater Number of Switches (NoS) in a ring topology. With the maximum value the Number of Switches (NoS) in a ring topology is reduced to NoS<15		

Table 31 – Maximum packet size for MRP

Parameter	Value	Comment
MRP test frame size	≤ 98 octets	Maximum packet size of a MRP test frame when used together with this document.

8.1.4.4   Precision transparent clock protocol

The allowed time values for PTCP defined in IEC 61158–6–10 are shown in Table 32 and Table 33.

Table 32 – Maximum time values for PTCP

Parameter	Value	Comment
Max Delay Request Repeat	5	—
Max Delay Response Time	< 10 ms	Recommended
Max Delay Response Time	< 25 ms	Mandatory
Max Bridge Delay [a]	≤ 4 ms	Recommended
Max Bridge Delay [a]	≤ 40 ms	Mandatory
Bridge Delay measurement accuracy [b]	≤ 50 ns	Recommended
Bridge Delay measurement accuracy [b]	≤ 100 ns	Mandatory
Timestamp accuracy	≤ 8 ns	Recommended
Timestamp accuracy	≤ 10 ns	Mandatory
Line/Cable Delay measurement accuracy [c]	≤ 20 ns	Recommended
Line/Cable Delay measurement accuracy [c]	≤ 50 ns	Mandatory
[a] For forwarding PTCP Sync Frames		
[b] Measurement of the Bridge Delay may have a jitter but should be offset free ("zero mean")		
[c] Measurement of the Line/Cable Delay may have a jitter but should be offset free ("zero mean")		

Table 33 – Precision of timers used for PTCP

Parameter	Value	Comment
"DelayT" deviation	[-0; +100 ms]	—
"LineT" deviation	[-0; +100 ms]	—

8.1.4.5 Time synchronization

The allowed time values for time synchronization using IEEE 802.1AS are shown in Table 34.

Table 34 – Maximum deviation values for time synchronization

Parameter	Value
Deviation [a] between SyncMaster (Grandmaster) and an arbitrary SyncSlave	< 100 µs
Deviation [a] between two arbitrary SyncSlaves	< 200 µs
[a] Measurement principle from PTCP applies	

8.1.4.6 Link layer discovery protocol

8.1.4.6.1 General

IEC 61158–6–10 uses IEEE 802.1AB according IEEE 802.1AB-2016, 11.3.1 in version 1 mode together with version 1 MIB. The additional support of version 2 mode and version 2 MIBs is optional.

The IEEE 802.1AB-2016, 9.2.5.20 defined variable txNow: = TRUE is used concurrently with any change of the fields of the LLDP-PDU. In this case, a node transmits LLDP PDUs "on data change".

The IEEE 802.1AB-2016 uses the ChassisID/PortID as neighborhood "TAG" to support virtualization. PROFINET IO defines the SourceMAC as additional "TAG" to make sure that

"Assigning a name" leads immediately to an updated entry for a neighbor. Thus, false "Multiple neighbors" diagnosis shall be avoided.

Enabling Egress Filtering for LLDP at a port may lead to disabled receiving of LLDP frames at the same port, too.

8.1.4.6.2   Parameter

The allowed time values for LLDP defined in IEC 61158–6–10 and IEEE 802.1AB are shown in Table 35.

Table 35 – Maximum time values for LLDP

Parameter	Value	Comment
msgTxHold	4	Multiplier for msgTxInterval to calculate the txTTL.
msgTxInterval	5 s [-0;+1 s]	Time between two consecutive LLDP frames without any content change during steady state operation.
txTTL	21 s [-0;+1 s]	Duration for which an information from a neighbor is stored.
txNow	TRUE	Immediate transmission of a LLDP frame is used, whenever a change of the content of the local LLDP data or of the neighborhood is detected.
Neighborhood	1	Minimum stored neighbors in the Neighborhood. Recommended are up to 4.

8.1.4.7   Remote procedure call

8.1.4.7.1   General

UUID are created according to ISO/IEC 9834-8.

8.1.4.7.2   RPC client

A RPC client shall use only one RPCActivityUUID for one Application Relation. This may be created before Connect and deleted after Release.

An IO device sending an Application Ready request works as a RPC client, thus the RPC client rules applies.

Any tool (e.g. Diagnosis Tool or Topology Scanner) using Implicit Read works as a RPC client, thus the RPC client rules applies.

8.1.4.7.3   RPC server

A RPC server shall provide RPC resources for each supported Application Relation according to Table 36 and Table 37.

Table 38 shows the number of ImplicitARs which shall be available at an IO device.

An IO controller receiving an Application Ready indication works as a RPC server, thus the RPC server rules applies.

Table 36 – Required RPC resources

Parameter	Comment
IOCARSingle	For each concurrently supported AR at least one resource.
IOSAR	For each concurrently supported AR at least one resource.
IOCARSR	For each concurrently supported AR at least two or four resources, one for each AR of the ARset.
DeviceAccess	For each concurrently supported AR at least one resource.
ImplicitAR	For each concurrently supported access at least one resource. This access shall not influence the resources of the other AR types.

Table 37 – Required RPCActivityUUID resources

Parameter	Comment
Number of concurrently supported RPCActivityUUID resources	Shall cover the number of supported ARs including Implict Read. Value need to take into account the expected number of clients concurrently using Implicit Read and shut down/restart behavior.

Table 38 – Number of ImplicitARs

Number of ImplicitARs	Required	Comment
1	Mandatory	Concurrently supported ImplicitARs
4	Recommended	
Other	Optional	

8.1.4.8 Data Hold Time

The Data Hold Time is calculated according IEC 61158-6-10, 5.2.4.66 and its range is shown in Table 39.

Table 39 – Data Hold Time deviation

Parameter	Value	Meaning
Data Hold Time deviation	Minimum (Data Hold Time) Maximum (2 × Data Hold Time; 10 ms)	The implementation shall try to stay as close as possible to the calculated minimal Data Hold Time value. It shall not exceed the maximum value.

8.1.4.9 RTA Timeout

The RTA Timeout is calculated according IEC 61158-6-10, 5.2.4.32 and its range is shown in Table 40.

Table 40 – RTA Timeout deviation

Parameter	Value	Meaning
RTA Timeout deviation	[-0; +100 ms]	—

8.1.4.10 LogBookData

The minimum number of entries for LogBookData are shown in Table 41.

Table 41 – Number of LogBookData entries

Node	Value	Meaning
IO device	16	At least 16 entries shall be supported
IO controller	128	At least 128 entries shall be supported

8.1.4.11 Simple Network Management Protocol

Table 42 and Table 43 shows the SNMP definitions which shall be supported together with this document.

Table 42 – Community string

Community string	Access	Comment
public	Read only	Allow only read
private	Read / Write	Allow write if supported by the addressed object

Table 43 – SNMP timeout values

Service	Timeout	Comment
SNMP Set	Recommended: < 3 s Mandatory: < 10 s	Expected maximum response delay
SNMP Get	Recommended: < 3 s Mandatory: < 10 s	Expected maximum response delay
SNMP GetNext	Recommended: < 3 s Mandatory: < 10 s	Expected maximum response delay

8.1.4.12 Dynamic Host Configuration Protocol

Table 44 shows the DHCP options which shall be supported together with this document, in case the optional feature DHCP is supported.

Table 44 – DHCP client

Option	Comment
Option 1: Subnet Mask	Mandatory
Option 3: Next Gateway	Mandatory
Other	Optional

8.1.4.13 System Redundancy and Dynamic Reconfiguration

8.1.4.13.1 General

Table 45 shows the times used by System Redundancy and Dynamic Reconfiguration.

Table 45 – System Redundancy times

Parameter	Value	Comment
Maximum Takeover Time MTOT_short	Range: 100 ms – 300 s Accuracy: [-0;+1 s]	Implemented in CTLSRL, as a watchdog, to monitor the CMSRL of a device. Complementary to the MSOT_primary.
Maximum Takeover Time MTOT_long	Range: 300 s Accuracy: [-0;+1 s]	Implemented in CTLSRL, as a watchdog, to monitor the CMSRL of a device. Complementary to the MSOT_backup.
Maximum Switchover Time MSOT_primary	Range: 1 ms – 60 s Accuracy: [-100%;+0 s]	Implemented in CMSRL, as a watchdog, to monitor the CTLSRL of a controller. Complementary to the MTOT_short.
Maximum Switchover Time MSOT_backup	Range: 1 ms – 60 s Accuracy: [-100%;+0 s]	Implemented in CMSRL, as a watchdog, to monitor the CTLSRL of a controller. Complementary to the MTOT_long.
Redundancy Data Hold Time RDHT	Range (optional): 3 ms – 199 ms Range (mandatory): 200 ms – 65 535 ms Accuracy (Value ≤ 100 ms): [-0;+10 ms] Accuracy (Value ≤ 1 s): [-0;+100 ms] Accuracy (Value ≤ 65 s): [-0;+300 ms]	Implemented in CMSRL, as a watchdog, to monitor the CTLSRL of a controller and the controller itself.

8.1.4.13.2 Dynamic Reconfiguration – changeable parameters

8.1.4.13.2.1 General

Dynamic Reconfiguration supports bumpless change of parameters. Some parameters are changeable bumpless others are not.

Table 46, Table 47, Table 48, and 8.1.4.13.2.5 specific the expected behavior of an IO device supporting Dynamic Reconfiguration.

8.1.4.13.2.2 Address parameters

Table 46 shows that MAC address, IP suite, NameOfStation, and RPC Parameters are not bumpless changeable.

Table 46 –Address parameter

Parameter	Changeable bump less Yes/No
MAC	No
IP	No
NameOfStation	No
RPC Parameters	No

8.1.4.13.2.3   Application Relation parameters

Table 47 shows the list of all changeable AR-Parameters which an IO device shall support.

Adding or removing submodules changes all fields (e.g. ModuleIdentNumber, SubmoduleIdentNumber …) which contain information about the used submodules.

Table 47 – AR Parameters

Service, BlockType acc. Protocol	Parameter	Changeable bumpless Yes/No
Connect.req, ARBlockReq	ARType	No
	ARUUID	Yes
	SessionKey	Yes
	CMInitiatorMACAdd	No
	CMInitiatorObjUUID	No
	ARProperties	No
	CMInitiatorActivityTimeoutFactor	No
	CMInitiatorUDPRTPort	Yes
	StationNameLength	No
	CMInitiatorStationName	No
Connect.req, IOCRBlockReq	Number of IOCRBlocks	Yes
	IOCRType	No
	IOCRReference	Yes
	LT	No
	IOCRProperties (RTClass)	No
	DataLength	Yes
	FrameID	Yes
	SendClockFactor	No
	ReductionRatio	Yes
	Phase	Yes
	Sequence	Yes
	FrameSendOffset	No
	DataHoldFactor	Yes
	IOCRTagHeader	No
	IOCRMulticastMACAdd	Yes
	API	Yes
	SlotNumber	Yes
	SubslotNumber	Yes
	IODataObjectFrameOffset	Yes
Connect.req, ExpectedSubmodBlockReq	API	Yes
	SlotNumber	Yes
	ModuleIdentNumber	Yes
	ModuleProperties	Yes
	SubslotNumber	Yes
	SubmoduleIdentNumber	Yes
	SubmoduleProperties	Yes

Service, BlockType acc. Protocol	Parameter	Changeable bumpless Yes/No
Connect.req, AlarmCRBlock	AlarmCRType	No
	LT	No
	AlarmCRProperties	No
	RTATimeoutFactor	Yes
	RTARetries	Yes
	LocalAlarmReference	Yes
	MaxAlarmDataLength	No
	AlarmCRTagHeaderHigh	No
	AlarmCRTagHeaderLow	No
Connect.req, SRInfoBlock	RedundancyDataHoldFactor (RDHF)	Yes
	SRProperties	No

8.1.4.13.2.4 PDEV parameters

Table 48 shows the list of all changeable PDEV parameters which an IO device shall support.

Table 48 – PDEV parameters

PDEV Data Record	Parameterblock	Change allowed Yes/No
PDPortDataCheck	CheckPeers	Yes
	CheckLineDelay	Yes
	CheckMAUType	Yes
	CheckLinkState	Yes
	CheckSyncDifference	Yes
	CheckMAUTypeDifference	Yes
PDPortDataAdjust	AdjustDomainBoundary (Sync)	No
	AdjustMulticastBoundary	No
	AdjustMAUType	Yes [a]
	AdjustLinkState	Yes [a]
	AdjustPeerToPeerBoundary	Yes
	AdjustDCPBoundary	Yes
	AdjustPreambleLength	No
PDPortFODataAdjust	—	Yes
PDPortFODataCheck	—	Yes
PDInterfaceFSUDataAdjust	—	No
PDInterfaceAdjust	—	No
PDInterfaceMrpDataAdjust, PDInterfaceMrpDataCheck, PDPortMrpDataAdjust, PDPortMrpIcDataAdjust, PDPortMrpIcDataCheck	—	No
PDIRData, PDSyncData, PDIRSubframeData	—	No

PDEV Data Record	Parameterblock	Change allowed Yes/No
PDNCDataCheck	—	No
a　Port deactivation or MAUType change causes link down of this port		

8.1.4.13.2.5　Submodule parameters

Whether profile or vendor specific parameters of a submodule are able to be changed bumpless or not is in the responsibility of the IO device vendor.

8.1.5　Communication classes

8.1.5.1　General

All communication classes allow IEEE 802 series and IETF communications combined with the RTE specific additions. Communication classes are:

- RT Class 1 (content specified in attribute RT_CLASS_1, see IEC 61158–5–10, 6.3.4.2.2),

- RT Class 2 (legacy, content specified in attribute RT_CLASS_2, see IEC 61158–5–10, 6.3.4.2.2), and

- RT Class 3 (content specified in attribute RT_CLASS_3, see IEC 61158–5–10, 6.3.4.2.2), and

- RT Class UDP (content specified in attribute RT_CLASS_UDP, see IEC 61158–5–10, 6.3.4.2.2).

RT Class UDP is an optional communication class. It can be used without and in combination with RT Class 1, RT Class 2, and RT Class 3. The support of communication classes is shown in Table 49.

Table 49 – Communication classes applicable in conformance classes

Communication classes	Conformance classes		
	A	B	C
RT_CLASS_1 [a]	Mandatory	Mandatory	Mandatory [e]
RT_CLASS_2 [b, d]	—	—	Only for legacy nodes
RT_CLASS_3 [c]	—	—	Mandatory [d]
RT_CLASS_UDP	Optional	Optional	Optional
a　Real-time (RT) without bandwidth allocation, Traffic Class GREEN.			
b　Isochronous real-time (IRT) with bandwidth allocation, Traffic Class ORANGE.			
c　Isochronous real-time (IRT) with bandwidth allocation, Traffic Class RED.			
d　The use of RT_CLASS_2 is not intended.			
e　Whether – the support of RT_CLASS_1 is mandatory or optional, and – the support of ReductionRatio ≠ 1 is mandatory or optional, depends on the GSD attribute "IsochroneModeRequired".			

8.1.5.2　Communication performance parameters

The values are shown in Table 50.

NOTE   The inter frame gap (12 octets at the transmitter and 8 octets at the receiver) of ISO/IEC/IEEE 8802-3 applies.

Table 50 – Communication performance parameters

Parameter	Value	Meaning
REDBeginSafetyMargin	Minimum: 0 ns Maximum: 1 640 ns	This performance parameter is a RT_CLASS_3 property.
MinSupportedFSO	Minimum: 1 280 ns (using Short Preamble), 1 760 ns (using Long Preamble) Maximum: 5 000 ns	This performance parameter is a RT_CLASS_3 property.
MinRTC3Gap	Minimum: 1 120 ns Maximum: 2 000 ns	This performance parameter is a RT_CLASS_3 property.
REDEndSafetyMargin	0 ns	This performance parameter is a RT_CLASS_3 property.
MaxFrameStartTime	Maximum: 5 000 ns	This performance parameter is a RT_CLASS_1 / RT_CLASS_2 / RT_CLASS_UDP property.
MinNRTGap	Minimum: 960 ns Maximum: 2 000 ns	This performance parameter is a RT_CLASS_1 / RT_CLASS_2 / RT_CLASS_UDP property.

8.1.5.3   RT_CLASS_3 bridges

The values for RT_CLASS_3 bridges are shown in Table 51.

Table 51 – Parameters for RT_CLASS_3 bridges

Parameter	Value	Meaning
Max Retention Time	20 µs (mandatory) 4 ms (optional)	This performance parameter is a RT_CLASS_3 bridge property.
Frame send offset deviation	Mandatory ≤ 10 ns	This performance parameter is a RT_CLASS_3 bridge property.
RFSafetyMargin	0 ns ≤ Mandatory ≤ 100 ns	This performance parameter is a RT_CLASS_3 bridge property if FrameDataProperties.ForwardingMode:= "Relative mode" is supported
NumberOfRTC3Forwarder	Mandatory ≥ 128	This performance parameter is a RT_CLASS_3 bridge property. It defines the maxmium network diameter reachable for a RT_CLASS_3 domain. Both InputCRs and OutputCRs are counted. Example: The maximum network diameter with NumberOfRTC3Forwarder:= 128 is – 64 nodes (without MRPD), and – 32 nodes (with MRPD).
MaxRTC3BridgeDelay	Recommended: ≤ 2 µs Mandatory: ≤ 10 µs	This performance parameter is a RT_CLASS_3 bridge property. It defines the maxmium bridge delay for RT_CLASS_3 packets.

8.1.5.4   Transmitter

8.1.5.4.1   RT_CLASS_3 transmitter

The values for a RT_CLASS_3 transmitter are shown in Table 52.

Table 52 – FrameSendOffset deviation

Parameter	Value	Meaning
Frame send offset deviation	Node with RT_CLASS_3 bridge Mandatory ≤ 10 ns End node [a] Recommended ≤ 10 ns	This performance parameter is a RT_CLASS_3 transmitter property.
[a] The value of the deviation shall be as low as needed to avoid any disturbance in a RT_CLASS_3 domain		

NOTE   The deviation measureable on the MDI (media dependent interface) depends on the added jitter of the transition from the MAC, MII to MDI.

8.1.5.4.2   RT_CLASS_1 / RT_CLASS_UDP transmitter

The values for a RT_CLASS_1 / RT_CLASS_UDP transmitter are shown in Table 53.

Table 53 – FrameSendOffset deviation for RT_CLASS_1 / RT_CLASS_UDP

Parameter	Value	Meaning
Frame send offset deviation	Minimum (Less than 10 % of the used update interval [a]; 10 ms)	This performance parameter is a RT_CLASS_1 / RT_CLASS_UDP transmitter property.
[a] The update interval (UI) is calculated as $UI = SCF \times RR \times 31{,}25\mu s$ with the data from the used IOCR		

NOTE   The deviation measureable on the MDI (media dependent interface) depends on the added jitter of the transition from the MAC, MII to the MDI.

8.1.5.5   RT_CLASS_3 node

The values for a RT_CLASS_3 node are shown in Table 54.

Table 54 – Minimum FrameSendOffset

Parameter	Value	Meaning
Minimum frame send offset [a]	SendClockFactor $\geq$ 8: Mandatory ≤ 5 000 ns	This performance parameter is a RT_CLASS_3 transmitter, receiver and forwarder property.
	SendClockFactor < 8: Mandatory ≤ 2 000 ns	
[a] The real value, if lower is stated in the GSD attribute "MinFSO".		

8.1.5.6   Synchronization for RT_CLASS_3

The performance parameters of a PTCP control loop are shown in Table 55.

Table 55 – PTCP control loop

Parameter	Value	Meaning
Allowed frequency changing speed	Mandatory $\leq 5 \; \dfrac{\mu Hz}{Hz}\Big/_{s}$	This performance parameter is a sync slave property.

8.1.5.7   Fragmentation

Table 56 shows the allowed maximum frame size transmitted by a node in the GREEN or YELLOW period. This definition does not apply for nodes with FragmentationType == Dynamic.

Table 56 – Maximum frame size

SendClockFactor	Condition	Maximum frame size
1 – 2	FragmentationType [a] == Static	128 octets
3 – 7	FragmentationType [a] == Static	
8 – 128	FragmentationType [a] == Static && FrameDetails.FragmentationMode == Fragmentation enabled	256 octets
	! FragmentationType [a] || FrameDetails.FragmentationMode == Fragmentation disabled	Maximum ISO/IEC/IEEE 8802-3 frame
[a] See GSDML specification for the definition of this attribute.		

8.1.6   Media redundancy classes

Media redundancy classes are:

- RED_CLASS_1:

  Loop prevention and ring redundancy for IEEE 802 and IETF communications combined with the RTE specific additions RT_CLASS_1 and RT_CLASS_UDP.

  Class behavior distinguishes between manager (MRP Ring and/or MRP Interconnection) and client (MRP Ring and/or MRP Interconnection) as specified in IEC 61158–5–10, Media Redundancy ASE

- RED_CLASS_3:

  Loop prevention and ring redundancy for IEEE 802 and IETF communications in conjunction (derived from RED_CLASS_1) with seamless media redundancy for rings with RT_CLASS_3.

NOTE 1   RED_CLASS_1 is called media redundancy protocol (MRP) and used in conjunction with RT_CLASS_1 and RT_CLASS_3. RED_CLASS_3 is called media redundancy for planned duplication (MRPD) and used in conjunction with RT_CLASS_3.

NOTE 2   RED_CLASS_3 offers ring redundancy and needs a protocol for loop prevention. RED_CLASS_1 offers loop prevention. That's why RED_CLASS_3 inherits RED_CLASS_1.

The support of multiple rings, in conjunction with at least 4 ports, is optional; the support of the coding and diagnosis extensions is recommended.

Support of media redundancy requires devices with at least 2 ports; usage is shown in Table 57 and Table 58.

At least one node in a ring shall support the manager role (Manager or Manager (Auto)) if one of the media redundancy classes is used.

Table 57 – Media redundancy class applicable in conformance classes

Media redundancy classes vs. roles	Conformance classes			
	A	B	C	
	RED_CLASS_1	RED_CLASS_1	RED_CLASS_1	RED_CLASS_3
MRC MRP Client	Optional	Optional	Optional	Optional
MRM / MRA MRP Manager or Auto Manager	Optional	Optional	Optional	Optional
MIC MRP Interconnection Client	Optional	Optional	Optional	Optional
MIM MRP Interconnection Manager	Optional	Optional	Optional	Optional

Table 58 – Media redundancy – additional forwarding rules

Additional Forwarding rules	Conformance classes					
	A		B		C	
	MRC MRP Client	MRM MRP Manager	MRC MRP Client	MRM MRP Manager	MRC MRP Client	MRM MRP Manager
Supported	Optional					

Table 59 shows the MRP startup modes for RED_CLASS_1 and RED_CLASS_3 after PowerOn with repect to the supported roles.

Table 59 – Media redundancy startup mode

MRC MRP Client	MRM MRP Manager	MRA MRP Manager (Auto)	Possible startup mode	Preferred startup mode
YES	NO	NO	OFF or Client	Client
YES	YES	NO	OFF or Client or Manager	Depending on the product, either Client or Manager
YES	YES	YES	OFF or Client or Manager or Manager (Auto)	Manager (Auto)

8.1.7   Media classes

Media classes are:

- Wired
- Fiber optic
- Wireless

NOTE   If an interface uses media class "wireless", the definitions made for media class "wired" may not apply.

8.1.8   Application classes

8.1.8.1   Definition

Devices supporting a specific application class shall support additional features beyond those required for the particular conformance class. Those features are described below in detail for the specific application class.

The following application classes are defined:

- **Isochronous application** (e.g. motion control)

NOTE   Isochronous clock synchronization is a communication class feature and not an application class feature.

- **High availability**
- **Process automation**
- **High performance**
- **Controller to controller**
- **Functional safety**
- **Energy saving**

The support of application classes is shown in Table 60 and Table 61:

**Table 60 – Application classes applicable in conformance classes
for IO device and IO controller**

Application classes	Conformance classes		
	A	B	C
Isochronous application	—	—	Optional
High availability	Optional [a]	Optional	Optional
Process automation	Optional [a]	Optional	Optional
High performance	—	—	Optional
Controller to controller	—	Optional	Optional
Functional safety	Optional [a]	Optional	Optional
Energy saving	Optional [a]	Optional	Optional
[a] Not recommended			

Table 61 – Application classes applicable in conformance classes for network components

Application classes	Conformance classes		
	A	B	C
Isochronous application	—	—	—
High availability	—	—	—
Process automation	—	—	—
High performance	—	—	—
Controller to controller	—	—	—
Functional safety	—	—	—
Energy saving	—	—	—

8.1.8.2 Application class "Isochronous application"

Devices (i.e. IO device and IO controller) supporting the application class "isochronous application" shall support the following services additionally to the ones selected by the appropriate conformance class.

Application layer services for a device are defined in IEC 61158–5–10. Table 62 holds the application layer service selections from IEC 61158–5–10 to be supported additionally for this application class.

Table 62 – Application class "isochronous application" AL service selection

Clause	Header	Presence	Constraints
7.3.2.4	Isochronous Mode Application Class	YES	—

Application layer protocols for a device are defined in IEC 61158–6–10. Table 63 holds the application layer protocol selections from IEC 61158–6–10 to be supported additionally for this application class.

Table 63 – Application class "isochronous application" AL protocol selection component

Clause	Header	Presence	Constraints
—		—	—

8.1.8.3 Application class "High Availability"

Devices (i.e. IO device and IO controller) supporting the application class "high availability" shall support the following services additionally to the ones selected by the appropriate conformance class.

Application layer services for a device are defined in IEC 61158–5–10. Table 64 holds the application layer service selections from IEC 61158–5–10 to be supported additionally for this application class.

Table 64 – Application class "high availability" AL service selection

Clause	Header	Presence	Constraints
7.3	ASEs	Partial	—
7.3.1	AR ASE	YES	At least one ARset (mandatory); ARType IOCAR_SR and service Prm Begin shall be supported; AR switchover (backup, primary) shall be supported;
7.3.1.6	Record Data class	YES	Combined Object Container shall be supported by IO device and IO controller

Application layer protocols for a device are defined in IEC 61158–6–10. Table 65 holds the application layer protocol selections from IEC 61158–6–10 to be supported additionally for this application class.

Table 65 – Application class "high availability" AL protocol selection component

Clause	Header	Presence	Constraints
4.5	Time synchronization	If needed	Mandatory for IO device or IO controller with more than one port and optional for devices with one port
4.6.1	Media redundancy and loop prevention	YES, if at least two ports are available	MRP client (mandatory); Additional forwarding rules (mandatory); MRP manager (optional)
4.6.2	Seamless media redundancy	If needed	—
5.2.4.8	Coding of the field ARProperties	YES	The flag ARProperties.CombinedObjectContainer shall be supported
5.2.29	Coding section related to report system	If needed	For an IO device
5.6.3.9	Context Management Prm Begin End Device	YES	For an IO device
5.6.3.13	Context Management System Redundancy Layer Device	YES	For an IO device
5.6.3.13.6	Additional rules for Dynamic Reconfiguration	YES	For an IO device
5.6.4.11	Context Management Prm Begin End Controller	YES	For an IO controller
5.6.4.13	Context Management System Redundancy Layer Controller	YES	For an IO controller

8.1.8.4 Application class "Process automation"

Devices (i.e. IO device and IO controller) supporting the application class "process automation" shall support the following services additionally to the ones selected by the appropriate conformance class.

Table 66 – Basis application class for "process automation"

Basis application class	Comments
High availability	Process automation is based on the definitions of application class "High availability"

Application layer services for a device are defined in IEC 61158–5–10. Table 66 and Table 67 holds the application layer service selections from IEC 61158–5–10 to be supported additionally for this application class.

Table 67 – Application class "process automation" AL service selection

Clause	Header	Presence	Constraints
7.3.4.1.2	Severity	YES	Diagnosis model covering the five different severities (mandatory)
Annex A	Device instances	YES	"Instance model and device addresses" with at least two instances of an IO device (mandatory)

Application layer protocols for a device are defined in IEC 61158–6–10. Table 66 and Table 68 holds the application layer protocol selections from IEC 61158–6–10 to be supported additionally for this application class.

Table 68 – Application class "process automation" AL protocol selection component

Clause	Header	Presence	Constraints
5.2.8	Coding section related to Alarm and Diagnosis PDUs	YES	Diagnosis coding covering the coding of the five different severities (mandatory)
4.3.1.4.18	Coding of the field DeviceRoleDetails	YES	"multiple IO device interfaces" (mandatory)
5.6.3.2.2	CMDEV Device Access state machine	YES	Shall be supported for additional engineering systems

8.1.8.5   Application class "High performance"

Devices (i.e. IO device and IO controller) supporting the application class "High performance" shall support the following values shown in Table 69 and Table 70.

Table 69 – Application class "High performance" features supported

Parameter	Value	Meaning
SendClockFactor	Less than 8	Communication cycles less than 250 µs
FastForwarding	Supported	—
Fragmentation	Supported	—
Preamble shortening	Supported	—
Dynamic frame packing	Supported	—

Table 70 – Application class "High performance" parameter values

Parameter	Value	Meaning
REDBeginSafetyMargin	≤ 1 µs	—
MinSupportedFSO	≤ 3 500 ns	Value using standard preamble
MinRTC3Gap	≤ 1 600 ns	—
REDEndSafetyMargin	0 ns	—
MaxFrameStartTime	≤ 3 500 ns	Value using standard preamble
MinNRTGap	≤ 1 600 ns	—
BridgeDelay	≤ 2 µs	Value using FastForwarding and standard preamble
MaxPortTxDelay	Recommended: ≤ 90 ns	The max value from ISO/IEC/IEEE 8802-3:2017 applies.

Parameter	Value	Meaning
MaxPortRxDelay	Recommended: ≤ 210 ns	The max value from ISO/IEC/IEEE 8802-3:2017 applies.
MaxDFP_Feed	Recommended: ≤ 500 ns ≤ 1 500 ns	—
Peer to peer jitter	≤ 250 ns	—

8.1.8.6 Application class "Controller to Controller"

Devices supporting the application class "Controller to Controller" shall support the following values shown in Table 71.

Table 71 – Application class "Controller to Controller" features supported

Parameter	Value	Meaning
IO controller	YES	—
IO device	YES	—
Controller to controller records	YES	Index range 0xF860 to 0xF86F Retrieval of the stored GSD shall be supported
Shared IO device support	YES	—
Shared Input support	YES	—
Number of ARs	4	The IO device shall support at least four concurrent ARs

8.1.8.7 Application class "Functional safety"

Devices (i.e. IO device and IO controller) supporting the application class "Functional safety" shall support the following services additionally to the ones selected by the appropriate conformance class.

Table 72 applies for an IO device and Table 73 for an IO controller.

Table 72 – Application class "Functional safety" features supported by IO device

Parameter	Value	Meaning
I&M0 record read support	YES	Each submodule supporting "Functional safety" should provide its own data.
I&M4 record read support	YES	Each submodule supporting "Functional safety" should provide its own data.
I&M4 record write support	NO	Each submodule supporting "Functional safety"
DCP service "Factory Reset" or "Reset to Factory"	Limitation	These services shall not influence the "Functional safety" application, e.g. iParameter. Particular the content of I&M4 record, inherited by the "Functional safety" application, shall not be reset.
ChannelErrorType range for "Functional safety" supported	YES	Each submodule supporting "Functional safety"
Upload&Retrieval alarm supported	OPTIONAL	Each submodule supporting "Functional safety"

Table 73 – Application class "Functional safety" features supported by IO controller

Parameter	Value	Meaning
Upload&Retrieval alarm supported	YES	For each submodule supporting "Functional safety"

8.1.8.8   Application class "Energy saving"

Devices (i.e. IO device and IO controller) supporting the application class "Energy saving" shall support the following services additionally to the ones selected by the appropriate conformance class.

Table 74 and Table 75 applies for an IO device and Table 76 for an IO controller.

Table 74 holds the application layer service selections from IEC 61158–5–10 to be supported additionally from a IO device for this application class.

Table 74 – Application class "Energy saving" AL service selection

Clause	Header	Presence	Constraints
7.3.5	PE ASE	YES	—

Table 75 – Application class "Energy saving" features supported by IO device

Parameter	Value	Meaning
PE_EntityFilterData record read support	YES	For each submodule supporting "Energy saving"
PE_EntityStatusData record read support	YES	For each submodule supporting "Energy saving"
Status alarm supported	YES	For each submodule supporting "Energy saving"

Table 76 – Application class "Energy saving" features supported by IO controller

Parameter	Value	Meaning
Status alarm supported	YES	For each submodule supporting "Energy saving"

8.1.9   Records

8.1.9.1   General

Different records are associated with conformance class A, B and C as shown in Table 77, Table 78, Table 79, Table 80, Table 81, and Table 82.

Table 77 – Index (user specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		**B**		**C**	
		R	**W**	**R**	**W**	**R**	**W**
0 – 0x7FFF	User specific RecordData	O / G		O / G		O / G	
R Read							
W Write							
M Mandatory							
O Optional							
G Defined by the GSD							

Table 78 – Index (subslot specific)

Value (hexadecimal)	Meaning of index	Conformance class						Applicable Sub-modules
		A		**B**		**C**		
		R	**W**	**R**	**W**	**R**	**W**	
0x8000	ExpectedIdentificationData for one subslot	M	—	M	—	M	—	All
0x8001	RealIdentificationData for one subslot	M	—	M	—	M	—	All
0x8002 – 0x8009	Reserved			—				—
0x800A	Diagnosis in channel coding for one subslot	M	—	M	—	M	—	All
0x800B	Diagnosis in all codings for one subslot	M	—	M	—	M	—	All
0x800C	Diagnosis, Maintenance, Qualified and Status for one subslot	M	—	M	—	M	—	All
0x800D – 0x800F	Reserved			—				—
0x8010	Maintenance required in channel coding for one subslot	M	—	M	—	M	—	All
0x8011	Maintenance demanded in channel coding for one subslot	M	—	M	—	M	—	All
0x8012	Maintenance required in all codings for one subslot	M	—	M	—	M	—	All
0x8013	Maintenance demanded in all codings for one subslot	M	—	M	—	M	—	All
0x8014 – 0x801D	Reserved			—				—
0x801E	SubstituteValue for one subslot	G		G		G		All
0x801F	Reserved			—				—
0x8020	PDIRSubframeData for one subslot	—		—		G		Interface
0x8021 – 0x8026	Reserved			—				—
0x8027	PDPortDataRealExtended for one subslot	G	—	G	—	G	—	Port
0x8028	RecordInputDataObjectElement for one subslot [a]	M	—	M	—	M	—	All
0x8029	RecordOutputDataObjectElement for one subslot	M	—	M	—	M	—	All
0x802A	PDPortDataReal for one subslot	L	—	L	—	L	—	Port
0x802B	PDPortDataCheck for one subslot See Table 84	M		M		M		Port
0x802C	PDIRData for one subslot	—		—		M		Interface
0x802D	PDSyncData for one subslot with SyncID value 0	—		G		M		Interface

Value (hexadecimal)	Meaning of index	A R	A W	B R	B W	C R	C W	Applicable Sub-modules
0x802E	Reserved (legacy)			—				—
0x802F	PDPortDataAdjust for one subslot See Table 83	M		M		M		Port
0x8030	IsochronousModeData for one subslot	—		—		G		All
0x8031	PDTimeData for one subslot	—		G		G		Interface
0x8032 – 0x804F	Reserved (legacy)	—		—		—		—
0x8050	PDInterfaceMrpDataReal for one subslot	G	—	G	—	G	—	Interface
0x8051	PDInterfaceMrpDataCheck for one subslot	G		G		G		Interface
0x8052	PDInterfaceMrpDataAdjust for one subslot	G		G		G		Interface
0x8053	PDPortMrpDataAdjust for one subslot	G		G		G		Port
0x8054	PDPortMrpDataReal for one subslot	G	—	G	—	G	—	Port
0x8055	PDPortMrpIcDataAdjust for one subslot	G		G		G		Port
0x8056	PDPortMrpIcDataCheck for one subslot	G		G		G		Port
0x8057	PDPortMrpIcDataReal for one subslot	G	—	G	—	G	—	Port
0x8058 – 0x805F	Reserved			—				—
0x8060	PDPortFODataReal for one subslot	G	—	G	—	G	—	Port
0x8061	PDPortFODataCheck for one subslot	G		G		G		Port
0x8062	PDPortFODataAdjust for one subslot	G		G		G		Port
0x8063 – 0x806F	Reserved			—				—
0x8070	PDNCDataCheck for one subslot	G		G		G		Interface
0x8071	PDInterfaceAdjust for one subslot	M		M		M		Interface
0x8072	PDPortStatistic for one subslot	O	—	M	—	M	—	Interface, Port
0x8073 – 0x807F	Reserved			—				—
0x8080	PDInterfaceDataReal for one subslot	M	—	M	—	M	—	Interface
0x8081 – 0x808F	Reserved			—				—
0x8090	PDInterfaceFSUDataAdjust	G		G		G		Interface
0x8091 – 0x909F	Reserved			—				—
0x80A0	Profiles covering energy saving – Record_0	G		G		G		All
0x80A1 – 0x80AE	Reserved for profiles covering energy saving			—				—
0x80AF	PE_StatusData for one subslot	G	—	G	—	G	—	All
0x80B0	CombinedObjectContainer	—	G	—	G	—	G	All
0x80B1 – 0x80BF	Reserved			—				—
0x80C0 – 0x80CE	Reserved for profiles covering reporting system			—				—
0x80CF	RS_AdjustObserver	G		G		G		All
0x80D0 – 0x80DF	Reserved for profiles covering condition monitoring			—				—
0x80E0 – 0x80EF	Reserved for profiles covering functional safety	G		G		G		Functional safety
0x80F0 – 0xAFEF	Reserved			—				—
0xAFF0	I&M0 [b]	M	—	M	—	M	—	All
0xAFF1	I&M1 [c, d]	O	G	O	G	O	G	All
0xAFF2	I&M2 [c, d]	O	G	O	G	O	G	All

Value (hexadecimal)	Meaning of index	Conformance class						Appli-cable Sub-modules
		A		B		C		
		R	W	R	W	R	W	
0xAFF3	I&M3 [c, d]	O	G	O	G	O	G	All
0xAFF4	I&M4 [c, e]	O	G	O	G	O	G	All
0xAFF5	I&M5 [f]	O	—	O	—	O	—	All
0xAFF6 – 0xAFFF	I&M6 – I&M15	O		O		O		All
0xB000 – 0xBFFF	Reserved for profiles	O		O		O		All

R   Read

W   Write

M   Mandatory

O   Optional

G   Defined by the GSD

L   Optional but support recommended for compatibility reasons

[a]   Optional for input submodules without Data.

[b]   Each submodule containing firmware should support this record to provide the defined versioning information.

[c]   If defined writeable by GSD also readable.

[d]   Mandatory, read- and writeable, for at least one submodule, e.g. interface submodule.

[e]   Handling defined by Functional Safety if used for Functional Safety submodules.

[f]   Used as I&M0 extension.

It is not necessary for a device application to generate diagnosis, maintenance or status information beyond the mandatory defined ones. However the data records 0x800A, 0x800B, 0x800C, 0x8010, 0x8011, 0x8012 and 0x8013 act as a filter to the diagnosis ASE. If the diagnosis ASE does not contain any information of the requested type(s), the data record shall be returned empty. It is not allowed to state that the record does not exist.

Table 79 – Index (slot specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xC000	ExpectedIdentificationData for one slot	M	—	M	—	M	—
0xC001	RealIdentificationData for one slot	M	—	M	—	M	—
0xC002 – 0xC009	Reserved	—					
0xC00A	Diagnosis in channel coding for one slot	M	—	M	—	M	—
0xC00B	Diagnosis in all codings for one slot	M	—	M	—	M	—
0xC00C	Diagnosis, Maintenance, Qualified and Status for one slot	M	—	M	—	M	—
0xC00D – 0xC00F	Reserved	—					
0xC010	Maintenance required in channel coding for one slot	M	—	M	—	M	—
0xC011	Maintenance demanded in channel coding for one slot	M	—	M	—	M	—
0xC012	Maintenance required in all codings for one slot	M	—	M	—	M	—

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xC013	Maintenance demanded in all codings for one slot	M	—	M	—	M	—
0xC014 – 0xCFFF	Reserved	—					
0xD000 – 0xDFFF	Reserved for profiles	O	—	O	—	O	—
R Read							
W Write							
M Mandatory							
O Optional							
G Defined by the GSD							

Table 80 – Index (AR specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xE000	ExpectedIdentificationData for one AR	M	—	M	—	M	—
0xE001	RealIdentificationData for one AR	M	—	M	—	M	—
0xE002	ModuleDiffBlock for one AR	M	—	M	—	M	—
0xE003 – 0xE009	Reserved	—					
0xE00A	Diagnosis in channel coding for one AR	M	—	M	—	M	—
0xE00B	Diagnosis in all codings for one AR	M	—	M	—	M	—
0xE00C	Diagnosis, Maintenance, Qualified and Status for one AR	M	—	M	—	M	—
0xE00D – 0xE00F	Reserved	—					
0xE010	Maintenance required in channel coding for one AR	M	—	M	—	M	—
0xE011	Maintenance demanded in channel coding for one AR	M	—	M	—	M	—
0xE012	Maintenance required in all codings for one AR	M	—	M	—	M	—
0xE013	Maintenance demanded in all codings for one AR	M	—	M	—	M	—
0xE014 – 0xE02F	Reserved	—					
0xE030	PE_EntityFilterData for one AR	G	—	G	—	G	—
0xE031	PE_EntityStatusData for one AR	G	—	G	—	G	—
0xE032 – 0xE03F	Reserved	—					
0xE040	MultipleWrite [b]	—	M	—	M	—	M
0xE041 – 0xE04F	Reserved	—					
0xE050	Legacy ARFSUDataAdjust [a] data for one AR	G [a]					
0xE051 – 0xE05F	Reserved for FastStartUp	—					

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xE060	RS_GetEvent	G	—	G	—	G	—
0xE061	RS_AckEvent	—	G	—	G	—	G
0xE062 – 0xEBFF	Reserved	—					
0xEC00 – 0xEFFF	Reserved for profiles	O	—	O	—	O	—

R   Read

W   Write

M   Mandatory

O   Optional

G   Defined by the GSD

a   A record ARFSUDataAdjust write shall be rejected, when using legacy startup mode.

b   The GSDML attribute shall be set accordingly.

Table 81 – Index (API specific)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		B		C	
		R	W	R	W	R	W
0xF000	RealIdentificationData for one API	M	—	M	—	M	—
0xF001 – 0xF009	Reserved	—					
0xF00A	Diagnosis in channel coding for one API	M	—	M	—	M	—
0xF00B	Diagnosis in all codings for one API	M	—	M	—	M	—
0xF00C	Diagnosis, Maintenance, Qualified and Status for one API	M	—	M	—	M	—
0xF00D – 0xF00F	Reserved	—					
0xF010	Maintenance required in channel coding for one API	M	—	M	—	M	—
0xF011	Maintenance demanded in channel coding for one API	M	—	M	—	M	—
0xF012	Maintenance required in all codings for one API	M	—	M	—	M	—
0xF013	Maintenance demanded in all codings for one API	M	—	M	—	M	—
0xF014 – 0xF01F	Reserved	—					
0xF020	ARData for one API	M	—	M	—	M	—
0xF021 – 0xF3FF	Reserved	—					
0xF400 – 0xF7FF	Reserved for profiles	O	—	O	—	O	—

R   Read

W   Write

M   Mandatory

O   Optional

G   Defined by the GSD

Table 82 – Index (device specific)

Value (hexadecimal)	Meaning of index	A		B		C	
		R	W	R	W	R	W
0xF800 – 0xF80B	Reserved			—			
0xF80C	Diagnosis, Maintenance, Qualified and Status for one device	M	—	M	—	M	—
0xF80D – 0xF81F	Reserved			—			
0xF820	ARData	M	—	M	—	M	—
0xF821	APIData	M	—	M	—	M	—
0xF822 – 0xF82F	Reserved						
0xF830	LogBookData	M	—	M	—	M	—
0xF831	PdevData			O	—	O	—
0xF832 – 0xF83F	Reserved			—			
0xF840	I&M0FilterData [a]	M	—	M	—	M	—
0xF841	PDRealData	M	—	M	—	M	—
0xF842	PDExpectedData	M	—	M	—	M	—
0xF843 – 0xF84F	Reserved			—			
0xF850	AutoConfiguration	G	—	G	—	G	—
0xF851 – 0xF85F	Reserved			—			
0xF860	Controller to controller communication GSD upload using UploadBLOBQuery and UploadBLOB	G	—	G	—	G	—
0xF861	Controller to controller communication Nested diagnosis info	G	—	G	—	G	—
0xF862 – 0xF86E	Reserved for Controller to controller communication 2…14			—			
0xF86F	Reserved for Controller to controller communication 15	G	—	G	—	G	—
0xF870	PE_EntityFilterData	G	—	G	—	G	—
0xF871	PE_EntityStatusData	G	—	G	—	G	—
0xF872 – 0xF87F	Reserved			—			
0xF880	AssetManagementData – Asset management info	G	—	G	—	G	—
0xF881 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF882 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF883 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF884 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF885 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF886 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF887 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF888 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF889 [b]	AssetManagementData – Asset management info	O	—	O	—	O	—
0xF88A – 0xFBFE	Reserved			—			
0xFBFF	Trigger index for the RPC connection monitoring	M	—	M	—	M	—
0xFC00 – 0xFFFF	Reserved for profiles	O	—	O	—	O	—

R	Read		
W	Write		
M	Mandatory		
O	Optional		
G	Defined by the GSD		
a	Each entry defines an owner of the responded I&M data. Submodules not stated in this list respond the values of their representative submodule.		
b	Each of this records may be available but shall only be supported if 0xF880 is available, too		

8.1.9.2 Record sub blocks

8.1.9.2.1 General

The following definitions applies if the protocol is defined for the implemented MAU type of the affected port.

8.1.9.2.2 PDPortDataAdjust

Different sub blocks of the PDPortDataAdjust record are associated with conformance class A, B and C as shown in Table 83.

Table 83 – PDPortDataAdjust (sub blocks)

Value (hexadecimal)	Meaning of sub block	Conformance class					
		A		**B**		**C**	
		R	W	R	W	R	W
—	AdjustDomainBoundary		—		M a		M
—	AdjustMulticastBoundary		—		M b		
—	AdjustMAUType		G g				M
—	AdjustLinkState		G				M
—	AdjustPeerToPeerBoundary		M c		M d		M e
—	AdjustDCPBoundary				M		
—	AdjustPreambleLength		—				M f

R	Read
W	Write
M	Mandatory
O	Optional
G	Defined by the GSD

a	Mandatory if PTCP is supported; optional specified by GSD in any other case
b	Mandatory if Multicast Communication relation is supported; optional specified by GSD in any other case
c	Only LLDP boundary is mandatory
d	LLDP and if supported PTCP and IEEE 802.1AS; these boundaries are mandatory
e	LLDP, PTCP and if supported IEEE 802.1AS; these boundaries are mandatory
f	Mandatory if the application class high performance applies; optional specified by GSD in any other case
g	Mandatory if fast startup is supported; optional specified by GSD in any other case

8.1.9.2.3   PDPortDataCheck

Different sub blocks of the PDPortDataCheck record are associated with conformance class A, B and C as shown in Table 84.

Table 84 – PDPortDataCheck (sub blocks)

Value (hexadecimal)	Meaning of index	Conformance class					
		A		**B**		**C**	
		R	**W**	**R**	**W**	**R**	**W**
—	CheckPeers				M		
—	CheckLineDelay	—		M[a]		M	
—	CheckMAUType			G		M	
—	CheckLinkState			G		M	
—	CheckSyncDifference			M[a]		M	
—	CheckMAUTypeDifference			M			

R   Read

W   Write

M   Mandatory

O   Optional

G   Defined by the GSD

[a]   Mandatory if PTCP is supported

8.1.10   Communication feature list

Table 85 shows at a glance a list of PROFINET features.

Table 85 – Communication feature list

Feature	Conformance Classes		
	A	**B**	**C**
Provider for multicast communication relation (MCR)	Optional		
Shared device	Optional		
Shared input	Optional		
Fast startup	Optional		
Device access	Optional		
Supervisor Application Relation	IO controller: — IO device: Recommended		
Implicit Application Relation	IO controller: Optional IO device: Mandatory		
AutoNameOfStationAssignment See CTLDINA in IEC 61158–6–10	IO controller: Recommended IO device: —		

8.1.11   Conformance class behaviors

8.1.11.1   General

CP 3/4, CP 3/5, and CP 3/6 specify the different node classes in the CPF 3 subclauses. The application classes are selected in conformance class. A CP is associated to a conformance

class. Media redundancy is selected in a conformance class. Table 86 specifies the required conformance class behaviors.

In this document the following communication profiles are specified for CPF 3:

- CP 3/4, see Table 86 and Table 95 conformance class A;
- CP 3/5, see Table 86 conformance class B;
- CP 3/6, see Table 86 conformance class C.

8.1.11.2 IO controller, IO device and IO supervisor

Table 86 shows the requirements for components with IO controller, IO device or IO supervisor functionality.

Table 86 – Conformance class behaviors

General classes	Conformance Classes			
	A		**B**	**C**
	Wireless	**Wired**		
CP	CP 3/4		CP 3/5	CP 3/6
Node classes [a] (see 8.1.3)	IO device, IO controller			
Media classes (see 8.1.7)	Wireless	Selection of wired or fiber optic		
Application classes	see 8.1.8			
Communication classes [b]	see 8.1.4.8			
Media redundancy classes	Only RED_CLASS_1 see 8.1.6	see 8.1.6		
Installation IEC 61784–5–3	—	Optional	YES	
Communication feature list	see 8.1.10			
ISO/IEC/IEEE 8802-3 "Media Access Control"	—	YES [i]		
IEEE 802.1Q [e] "MAC Bridges and Virtual Bridge LAN"	—		YES [c]	YES [d]
IEEE 802.1AB [j] „Link Layer Discovery Protocol"	Optional	YES [f]	YES	
IEEE 802.1AS "Timing and Synchronization"	Optional			
Wireless technologies selection	1. IEEE 802.11 [g] 2. IEEE 802.15.1	—	—	—
SNMP	Optional		YES	
LLDP-MIB [j] LLDP-EXT-DOT3-MIB [j] LLDP-EXT-PNO-MIB	Optional	Optional [k]	YES	
LLDP-EXT-DOT1-MIB	Optional			
IETF RFC 1213-MIB (MIB-2)	Optional [k]		YES [h]	
PNO MIB	Optional			

^a IO supervisor is out of scope of conformance class.

^b All conformance classes allow IETF communication combined with the RTE specific additions. The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

^c 1) CutThroughMode is recommended.
    2) "Discard on received frame in error" is optional when using the CutThroughMode.

^d 1) CutThroughMode is mandatory.
    2) "Discard on received frame in error" optional

^e 1) Priority tagging VLAN configuration, removal and modification of tag headers is optional.
    2) At least two priorities required, four should be supported and eight are recommended.
    3) RSTP optional or replaced by MRP.

^f Sending and receiving of LLDP frames is mandatory. The LLDP-MIB and their extensions are optional.

^g 1) At least EDCA part with four priorities supported
    2) Optional IEEE 802.11n.

^h See Table 87

ⁱ The support of Auto Negotiation with a link speed of at least 100 Mbit/s full-duplex is mandatory. All other MAU types stated in IETF RFC 4836 fulfilling this requirements (i.e. 1 Gbit/s full-duplex, 10 Gbit/s or 100 Gbit/s full-duplex) is optional.

^j IEEE 802.1AB-2009, 11.3.1. in version 1 mode together with version 1 MIB. The additional support of version 2 mode and version 2 MIBs is optional. The OIDs shown in Table 88, Table 89, Table 90, Table 91, Table 92, Table 93, and Table 94 shall be supported, other OIDs of the referenced MIBs should be supported.

^k If supported, the rules for the conformance class **B** apply

Table 87 – IETF RFC 1213-MIB (MIB-2) objects

OID tree entry	Object identification	Meaning
iso(1). org (3). dod(6). internet(1). mgmt(2). mib-2(1). system(1).	sysDescr(1), sysObjectID(2), sysUpTime(3), sysContact ^a(4), sysName ^a(5), sysLocation ^a(6), sysServices(7)	Mandatory
iso(1). org (3). dod(6). internet(1). mgmt(2). mib-2(1). interfaces(2).	ifNumber	Mandatory
iso(1). org (3). dod(6). internet(1). mgmt(2). mib-2(1). interfaces(2). ifTable(2). ifEntry.	ifIndex(1), ifDescr(2), ifType(3), ifMtu(4), ifSpeed(5), ifPhysAddress(6), ifAdminStatus(7), ifOperStatus(8)	Mandatory
iso(1). org (3). dod(6). internet(1). mgmt(2). mib-2(1). interfaces(2). ifTable(2). ifEntry.	ifInOctets(10), ifInDiscards(13) ^c, ifInErrors(14) ^c, ifOutOctets(16), ifOutDiscards(19) ^c, ifOutErrors(20) ^c	Mandatory ^b

^a These objects are writeable

^b These objects shall be supported for the physical ports "Port" and should be supported by the management port "Interface"

^c These objects should be supported

Table 88 – LLDP-MIB objects – range 1

OID tree entry	Object identification	Meaning
1.0.8802.1.1.2.1.1	lldpMIB.lldpObjects.lldpConfiguration	Mandatory
1.0.8802.1.1.2.1.1.7	.lldpConfigManAddrTable	
1.0.8802.1.1.2.1.1.7.1	.lldpConfigManAddrEntry	
1.0.8802.1.1.2.1.1.7.1.1	.lldpConfigManAddrPortsTxEnable	

Table 89 – LLDP-MIB objects – range 2

OID tree entry	Object identification	Meaning
1.0.8802.1.1.2.1.3	lldpMIB.lldpObjects.lldpLocalSystemData	Mandatory
1.0.8802.1.1.2.1.3.1	.lldpLocChassisIdSubtype	
1.0.8802.1.1.2.1.3.2	.lldpLocChassisId	
1.0.8802.1.1.2.1.3.7	.lldpLocPortTable	
1.0.8802.1.1.2.1.3.7.1	.lldpLocPortTableEntry	
1.0.8802.1.1.2.1.3.7.1.1	.lldpLocPortNum	
1.0.8802.1.1.2.1.3.7.1.2	.lldpLocPortIdSubtype	
1.0.8802.1.1.2.1.3.7.1.3	.lldpLocPortId	
1.0.8802.1.1.2.1.3.8	.lldpLocManAddrTable	
1.0.8802.1.1.2.1.3.8.1	.lldpLocManAddrTableEntry	
1.0.8802.1.1.2.1.3.8.1.1	.lldpLocManAddrSubtype	
1.0.8802.1.1.2.1.3.8.1.2	.lldpLocManAddr	

Table 90 – LLDP-MIB objects – range 3

OID tree entry	Object identification	Meaning
1.0.8802.1.1.2.1.4	lldpMIB.lldpObjects.lldpRemoteSystemsData	Mandatory
1.0.8802.1.1.2.1.4.1	.lldpRemTable	
1.0.8802.1.1.2.1.4.1.1	.lldpRemEntry	
1.0.8802.1.1.2.1.4.1.1.1	.lldpRemTimeMark	
1.0.8802.1.1.2.1.4.1.1.2	.lldpRemLocalPortNum	
1.0.8802.1.1.2.1.4.1.1.3	.lldpRemIndex	
1.0.8802.1.1.2.1.4.1.1.4	.lldpRemChassisIdSubtype	
1.0.8802.1.1.2.1.4.1.1.5	.lldpRemChassisId	
1.0.8802.1.1.2.1.4.1.1.6	.lldpRemPortIdSubtype	
1.0.8802.1.1.2.1.4.1.1.7	.lldpRemPortId	
1.0.8802.1.1.2.1.4.2	.lldpRemManAddrTable	
1.0.8802.1.1.2.1.4.2.1	.lldpRemManAddrEntry	
1.0.8802.1.1.2.1.4.2.1.1	.lldpRemManAddrSubtype	
1.0.8802.1.1.2.1.4.2.1.2	.lldpRemManAddr	

Table 91 – LLDP-EXT-PNO-MIB objects – range 1

OID tree entry	Object identification	Meaning
1.0.8802.1.1.2.1.5.3791.1.2	lldpMIB.lldpObjects.lldpExtensions.lldpXPnoMIB.lldpXPnoObjects.lldpXPnoLocalData	Mandatory
1.0.8802.1.1.2.1.5.3791.1.2.1	.lldpXPnoLocTable	
1.0.8802.1.1.2.1.5.3791.1.2.1.1	.lldpXPnoLocEntry	
1.0.8802.1.1.2.1.5.3791.1.2.1.1.1	.lldpXPnoLocLPDValue	
1.0.8802.1.1.2.1.5.3791.1.2.1.1.2	.lldpXPnoLocPortTxDValue	
1.0.8802.1.1.2.1.5.3791.1.2.1.1.3	.lldpXPnoLocPortRxDValue	
1.0.8802.1.1.2.1.5.3791.1.2.1.1.6	.lldpXPnoLocPortNoS	

Table 92 – LLDP-EXT-PNO-MIB objects – range 2

OID tree entry	Object identification	Meaning
1.0.8802.1.1.2.1.5.3791.1.3	lldpMIB.lldpObjects.lldpExtensions.lldpXPnoMIB.lldpXPnoObjects.lldpXPnoRemoteData	Mandatory
1.0.8802.1.1.2.1.5.3791.1.3.1	.lldpXPnoRemTable	
1.0.8802.1.1.2.1.5.3791.1.3.1.1	.lldpXPnoRemEntry	
1.0.8802.1.1.2.1.5.3791.1.3.1.1.1	.lldpXPnoRemLPDValue	
1.0.8802.1.1.2.1.5.3791.1.3.1.1.2	.lldpXPnoRemPortTxDValue	
1.0.8802.1.1.2.1.5.3791.1.3.1.1.3	.lldpXPnoRemPortRxDValue	
1.0.8802.1.1.2.1.5.3791.1.3.1.1.6	.lldpXPnoRemPortNoS	

Table 93 – LLDP-EXT-DOT3-MIB objects – range 1

OID tree entry	Object identification	Meaning
1.0.8802.1.1.2.1.5.4623.1.2	lldpMIB.lldpObjects.lldpExtensions.lldpXdot3MIB.lldpXdot3Objects.lldpXdot3LocalData	Mandatory
1.0.8802.1.1.2.1.5.4623.1.2.1.1.2	.lldpXdot3LocPortAutoNegEnabled	
1.0.8802.1.1.2.1.5.4623.1.2.1.1.4	.lldpXdot3LocPortOperMauType	

Table 94 – LLDP-EXT-DOT3-MIB objects – range 2

OID tree entry	Object identification	Meaning
1.0.8802.1.1.2.1.5.4623.1.3	lldpMIB.lldpObjects.lldpExtensions.lldpXdot3MIB.lldpXdot3Objects.lldpXdot3RemoteData	Mandatory
1.0.8802.1.1.2.1.5.4623.1.3.1.1.2	.lldpXdot3RemPortAutoNegEnabled	
1.0.8802.1.1.2.1.5.4623.1.3.1.1.4	.lldpXdot3RemPortOperMauType	

The conformance classes are laid out in such a way that a lower conformance class is a subset of a higher conformance class. Thus higher class devices are interoperable with lower class devices by using the capabilities of the lower class only.

Note however that a particular submodule of an IO device may enforce the IO controller to use isochronous mode operation (indicated with the GSDML attribute IsochroneModeRequired) and thus in consequence enforces the IO controller to use conformance class C. Such an IO device with that particular submodule will not be able to operate with an IO controller supporting only conformance class A and/or B.

8.1.11.3 Network components

Table 95 shows the requirements for network components without IO controller, IO device or IO supervisor functionality.

Table 95 – Conformance class behaviors for network components

General classes	Conformance Classes		
	A	A	A
CP	CP 3/4	CP 3/4	CP 3/4
Node classes (see 8.1.3)	Switch	Wireless access point	Wireless client
Media classes (see 8.1.7)	Selection of wired or fiber optic	Wireless	Wireless
Application classes	see 8.1.8		
Communication classes [a]	see 8.1.4.8		
Media redundancy classes	see 8.1.6	—	
Installation IEC 61784–5–3	Optional	—	
Communication feature list	—	—	
ISO/IEC/IEEE 8802-3 [e]	YES	—	
IEEE 802.1Q [b,c]	YES	—	
IEEE 802.1AB [f]	Recommended	Optional	
IEEE 802.1AS	Optional		
Wireless technologies selection	—	1. IEEE 802.11 [d] 2. IEEE 802.15.1	
SNMP	Recommended	Optional	
IETF RFC 1213-MIB (MIB-2) [g]	Recommended	Optional	
LLDP-MIB [f] LLDP-EXT-DOT1-MIB LLDP-EXT-DOT3-MIB LLDP-EXT-PNO-MIB	Recommended	Optional	

[a] All conformance classes allow IETF communication combined with the RTE specific additions. The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[b] 1) RSTP optional or replaced by MRP.
2) CutThroughMode is recommended.
3) "Discard on received frame in error" is optional when using the CutThroughMode.

[c] 1) Priority tagging VLAN configuration, removal and modification of tag headers is optional.
2) At least two priorities required, four should be supported and eight are recommended.

[d] 1) At least EDCA part with four priorities shall be supported.
2) Optional IEEE 802.11n.

[e] The support of Auto Negotiation with a link speed of at least 100 Mbit/s full-duplex is mandatory. All other MAU types stated in IETF RFC 4836 fulfilling this requirements (i.e. 1 Gbit/s full-duplex, 10 Gbit/s or 100 Gbit/s full-duplex) are optional.

8.1.11.4   MAC bridges

8.1.11.4.1   General

Each node containing a MAC bridge shall support wire speed forwarding concurrently for all ports under 100 % net load.

Forwarding resource protection/reservation for all supported queues/priorities is recommended.

8.1.11.4.2   CP 3/6

A switch shall support buffering of all data according to Table 96. This shall be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

Table 96 – Buffering capacity at 100 Mbit/s

Meaning	Value	
Buffering capacity (available "forwarding resources")	Recommended:	1 ms
	Mandatory:	500 µs

8.1.11.4.3   CP 3/4 and CP 3/5

A switch with less than eight ports shall provide buffering capacity according to Table 97, with eight and more ports according to Table 98. This shall be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

Table 97 – Buffering capacity for less than eight ports at 100 Mbit/s

Meaning	Value
Buffering capacity per port	10 240 octets

Table 98 – Buffering capacity for eight and more ports at 100 Mbit/s

Meaning	Value
Buffering capacity	81 920 octets

8.1.11.5   Interconnect

Network components can be used as leaves of a CP 3/6 network to connect CP 3/4 or CP 3/5 devices without losing the **C** conformance class capabilities. An example of connecting CP 3/4, CP 3/5, and CP 3/6 together is shown in Figure 3.
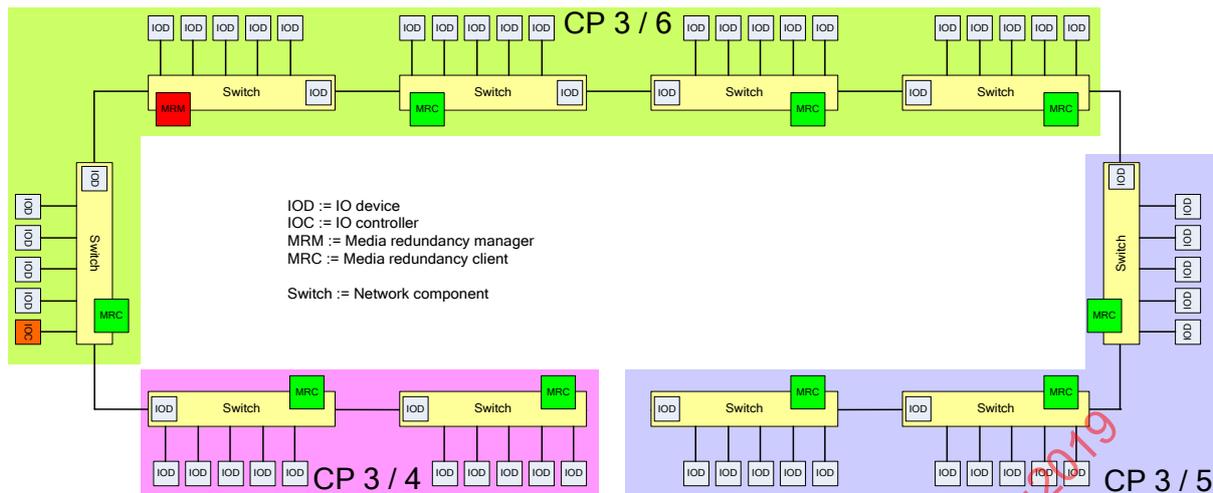
Figure 3 – Example of network topology using CP 3/4, CP 3/5, and CP 3/6 components

8.2 Profile 3/4

8.2.1 Physical layer

8.2.1.1 Media class wired and fiber optic

The physical layer shall be according to ISO/IEC/IEEE 8802-3.

The data rate shall be at least 100 Mbit/s and full-duplex mode shall be used at least for one port.

8.2.1.2 Media class wireless

The physical layer shall be a selection of IEEE 802.11 and IEEE 802.15.1.

If IEEE 802.11 is selected then the data rate shall be according to IEEE 802.11 and optional according to IEEE 802.11n, else the data rate shall be according IEEE 802.15.1.

8.2.2 Data link layer

8.2.2.1 General

The local injected non real time traffic of each node should be limited per millisecond according to Table 99 to avoid a network overload.

Table 99 – Link speed dependent local injection

Link speed	Principle value	Arithmetic value [per millisecond]	Used value [per millisecond]
100 Mbit/s	25 % of maximum	3 125 octets	3 072 octets
1 Gbit/s	25 % of maximum	31 250 octets	30 720 octets
10 Gbit/s	undefined	undefined	undefined

The number of octets can be calculated by Formula (11)

$$MaximumOctets = 1\ ms\ /\ DurationOctet[Link\ speed] \qquad (11)$$

$$25\ \% = MaximumOctets\ /\ 4$$

where

MaximumOctets	is the maximum number of octets possible;
1 ms	is the observation interval;
DurationOctet[]	is the duration of an octet as a function of link speed.

8.2.2.2   Media class wired and fiber optic

The data link layer shall be according to ISO/IEC/IEEE 8802-3, IEEE 802.1AB, and IEEE 802.1Q.

All management information bases (MIBs) are optional.

8.2.2.3   Media class wireless

The data link layer shall be a selection of IEEE 802.11 or IEEE 802.15.1.

Devices of the media class wireless using the IEEE 802.15.1 physical layer shall support adaptive frequency hopping (AFH). Furthermore these devices shall provide means to exclude frequencies used by IEEE 802.11 systems permanently from their hopping sequence.

All management information bases (MIBs) are optional.

8.2.3   Application layer

8.2.3.1   AL service selection

8.2.3.1.1   IO device

Application layer services for an IO device are defined in IEC 61158–5–10 Table 100 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 100 – CP 3/4: AL service selection for an IO device

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Concepts	YES	—
5	Data type ASE	YES	—
6	Communication model for common services	—	—
6.1	Concepts	YES	—
6.2	ASE data types	YES	—
6.3	Application Service Elements	—	—
6.3.1	Remote procedure call ASE	YES	—
6.3.2	Domain name system ASE	YES	Optional

Clause	Header	Presence	Constraints
6.3.3	Simple network management ASE	YES	Optional
6.3.4	IP suite ASE	YES	ICMP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.5	Real time cyclic ASE	YES	RT_CLASS_UDP is optional
6.3.6	Real time acyclic ASE	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.7	Discovery and basic configuration ASE	YES	—
6.3.8	Dynamic host configuration ASE	YES	Optional
6.3.9	IEEE 802.1AB ASE	YES	n.a. for wireless media
6.3.10	Media redundancy ASE	YES	See 8.1.6, n.a. for wireless media
6.3.11	Precision time control ASE	YES	Optional
6.3.12	IEEE 802.1AS ASE	YES	Optional
6.3.13	Virtual Bridges ASE	YES	n.a. for wireless media
6.3.14	MAC Bridges ASE	YES	Only applicable if a network component is integrated.
6.3.15	Fragmentation ASE	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
6.3.16	IEEE 802.3 ASE	YES	n.a. for wireless media
6.3.17	Common DL mapping ASE	—	—
6.3.17.1	Overview	YES	—
6.3.17.2	DL Mapping class specification	YES	—
6.3.17.3	DL Mapping service specification	—	—
6.3.17.3.1	P Data	YES	Optional; mandatory if Precision Time Control ASE is supported
6.3.17.3.2	N Data	YES	—
6.3.17.3.3	A Data	YES	—
6.3.17.3.4	C Data	YES	—
7	Communication model for decentralized periphery	—	—
7.1	Concepts	YES	—
7.2	ASE data types	YES	—
7.3	ASEs	—	—
7.3.1	AR ASE	YES	—
7.3.2	Real Identification ASE	YES	—
7.3.3	Communication Interface Management ASE	YES	—
7.3.4	Diagnosis ASE	YES	—
7.3.5	PE ASE	YES	Optional
7.3.6	LogBook ASE	YES	—
7.3.7	RS ASE	YES	Optional
7.3.8	Time ASE	YES	Optional
7.4	Application characteristics	YES	—
7.5	Summary of FAL services	—	—
7.5.1	IO device	YES	—
7.5.2	IO controller	NO	—
7.5.3	IO Supervisor	NO	—
Annex A	Device instances	YES	—

Clause	Header	Presence	Constraints
Annex B	Components of an Ethernet interface	Partial	Used when applicable
Annex C	Scheme of MAC address assignment	YES	—
Annex D	Measurement of the fast startup time	YES	—
Annex E	Dynamic Frame Packing	YES	Optional
Annex F	Precondition for Diagnosis	YES	—
—	Bibliography	YES	—

8.2.3.1.2 Network component

8.2.3.1.2.1 General

A network component can be integrated in an IO device or an IO controller. If so, then the requirements of an IO device and IO controller are applicable.

Alternatively the network component can be build as a non-integrated network component as a stand alone node.

The requirements from 8.1.11.4 apply.

8.2.3.1.2.2 Non-integrated network component

A non-integrated network component does not require Type 10 AL. Table 95 specifies the general network component behaviors.

The wireless bridge (2 access points or 1 access point and 1 client) shall support less then 128 ms propagation delay. An example of a wireless topology is shown in Figure 4.

Parameter of this AR consider the slower wireless link
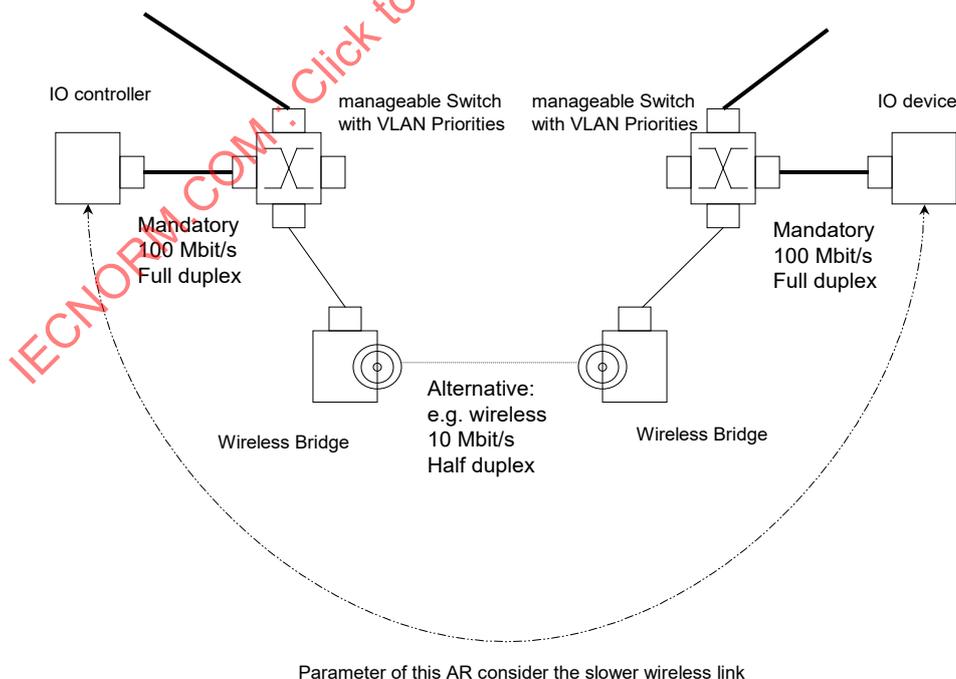
Figure 4 – Example of network topology with wireless segment

8.2.3.1.2.3 Integrated network component

Application layer services for a network component are defined in IEC 61158–5–10. Table 100 holds the application layer service selections from IEC 61158–5–10 for this profile.

8.2.3.1.3 IO controller

Application layer services for an IO controller are defined in IEC 61158–5–10. Table 100 changed by the content of Table 101 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 101 – CP 3/4: Additional AL service selection for an IO controller

Clause	Header	Presence	Constraints
7.1.4.2	IO controller	YES	Optional
7.1.4.3	IO supervisor	NO	—
7.1.4.4	IO parameter server	NO	—
7.1.4.5	IO device	NO	—
7.3.6	LogBook Data ASE	YES	Optional

8.2.3.1.4 IO supervisor

See 8.2.3.1.3.

8.2.3.1.5 Options

DHCP according to IETF RFC 2131 is an optional service.

DNS is an optional service for an IO controller and IO supervisor.

Media redundancy (see 8.1.6).

PTCP is an optional service. If PTCP is supported, the support of both sync master and redundant sync master are optional for an IO device. For an IO controller the support of sync master is mandatory and the support of redundant sync master optional.

8.2.3.2 AL protocol selection

8.2.3.2.1 IO device

Application layer protocols for an IO device are defined in IEC 61158–6–10. Table 102 holds the application layer protocol selections from IEC 61158–6–10 for this profile.

Table 102 – CP 3/4: AL protocol selection for an IO device and Network component

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviated terms, symbols and conventions	Partial	Used if needed
4	Application layer protocol specification for common protocols	—	—

Clause	Header	Presence	Constraints
4.1	FAL syntax description	YES	—
4.2	Transfer syntax	YES	—
4.2.1	Coding of basic data types	Partial	Used if needed
4.2.2	Coding section related to common basic fields	Partial	Used if needed
4.3	Discovery and basic configuration	YES	—
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	—
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	Bridges and End Stations	YES	—
4.13	IP suite		—
4.13.1	Overview	YES	—
4.13.2	IP/UDP syntax description	YES	—
4.13.3	IP/UDP transfer syntax	YES	—
4.13.4	ARP	—	—
4.13.4.1	General	YES	—
4.13.4.2	ARP Cache Control Machine	YES	Optional
4.14	Domain name system	YES	Optional
4.15	Dynamic host configuration	YES	Optional
4.16	Simple network management	YES	Optional
4.17	Common DLL Mapping Protocol Machines	YES	—
4.18	Additional definitions	YES	—
5	Application layer protocol specification for decentralized periphery	—	—
5.1	FAL syntax description	YES	—
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	—
5.5	FAL Service Protocol Machines	YES	—
5.5.1	Overview	YES	—
5.5.2	FAL Service Protocol Machine Device	YES	—
5.5.3	FAL Service Protocol Machine Controller	NO	—
5.6	Application Relationship Protocol Machines	—	—
5.6.1	Alarm Protocol Machine Initiator	YES	—
5.6.2	Alarm Protocol Machine Responder	YES	—
5.6.3	Device	YES	—
5.6.4	Controller	NO	—
5.7	DLL Mapping Protocol Machines	YES	—

Clause	Header	Presence	Constraints
Annex A	Unified establishing of an AR for all RT classes	YES	—
Annex B	Compatible establishing of an AR	YES	—
Annex C	Establishing of a device access AR	YES	—
Annex D	Establishing of an AR (accelerated procedure)	YES	—
Annex E	Establishing of an AR (fast startup procedure)	YES	—
Annex F	Example of the upload, storage and retrieval procedure	YES	—
Annex G	OSI reference model layers	YES	—
Annex H	Overview of the IO controller and the IO device state machines	YES	—
Annex I	Priority regeneration	YES	—
Annex J	Overview of the PTCP synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwidth usage	YES	—
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_3 is supported
Annex M	Time constraints for the forwarding of a frame	YES	—
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	—
Annex S	Example of a PrmBegin, PrmEnd and ApplRdy sequence	YES	—
Annex T	List of supported MIBs	YES	Optional
Annex U	Structure and content of BLOB	YES	If needed
Annex V	LLDP EXT MIB	YES	Optional
Annex W	Cross reference to the IEC 62439-2	YES	Optional; mandatory if MRP is supported
Annex X	Maintaining statistic counters for Ethernet	YES	—

8.2.3.2.2 Network component

8.2.3.2.2.1 General

See 8.2.3.1.2.1.

8.2.3.2.2.2 Non-integrated network component

A non-integrated network component does not require Type 10 AL. Table 95 specifies the general network component behaviors.

8.2.3.2.2.3 Integrated network component

Application layer protocols for an integrated network component are defined in IEC 61158–6–10. Table 102 specifies the clauses included in this profile.

8.2.3.2.3 IO controller

Application layer protocols for an IO controller are defined in IEC 61158–6–10. Table 103 specifies the clauses included in this profile.

Table 103 – CP 3/4: AL protocol selection for an IO controller

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviated terms, symbols and conventions	Partial	Used if needed
4	Application layer protocol specification for common protocols	—	—
4.1	FAL syntax description	YES	—
4.2	Transfer syntax	YES	—
4.2.1	Coding of basic data types	Partial	Used if needed
4.2.2	Coding section related to common basic fields	Partial	Used if needed
4.3	Discovery and basic configuration	YES	Support of the DCP function "ResetToFactory" recommended for IO controller
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	—
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	Bridges and End Stations	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	IP suite	—	—
4.13.1	Overview	YES	—
4.13.2	IP/UDP syntax description	YES	—
4.13.3	IP/UDP transfer syntax	YES	—
4.13.4	ARP	—	—
4.13.4.1	General	YES	—
4.13.4.2	ARP Cache Control Machine	YES	Optional
4.14	Domain name system	YES	Optional
4.15	Dynamic host configuration	YES	Optional
4.16	Simple network management	YES	Optional
4.17	Common DLL Mapping Protocol Machines	YES	—
4.18	Additional definitions	YES	—

Clause	Header	Presence	Constraints
5	Application layer protocol specification for decentralized periphery	—	—
5.1	FAL syntax description	YES	—
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	—
5.5	FAL Service Protocol Machines	YES	—
5.5.1	Overview	YES	—
5.5.2	FAL Service Protocol Machine Device	NO	—
5.5.3	FAL Service Protocol Machine Controller	YES	—
5.6	Application Relationship Protocol Machines	—	—
5.6.1	Alarm Protocol Machine Initiator	YES	—
5.6.2	Alarm Protocol Machine Responder	YES	—
5.6.3	Device	NO	—
5.6.4	Controller	YES	—
5.7	DLL Mapping Protocol Machines	YES	—
Annex A	Unified establishing of an AR for all RT classes	YES	—
Annex B	Compatible establishing of an AR	YES	—
Annex C	Establishing of a device access AR	YES	—
Annex D	Establishing of an AR (accelerated procedure)	YES	—
Annex E	Establishing of an AR (fast startup procedure)	YES	—
Annex F	Example of the upload, storage and retrieval procedure	YES	—
Annex G	OSI reference model layers	YES	—
Annex H	Overview of the IO controller and the IO device state machines	YES	—
Annex I	Priority regeneration	YES	—
Annex J	Overview of the PTCP synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwidth usage	YES	—
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_3 is supported
Annex M	Time constraints for the forwarding of a frame	YES	—
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 μs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	—
Annex S	Example of a PrmBegin, PrmEnd and ApplRdy sequence	YES	—
Annex T	List of supported MIBs	YES	Optional
Annex U	Structure and content of BLOB	YES	If needed
Annex V	LLDP EXT MIB	YES	Optional

Clause	Header	Presence	Constraints
Annex W	Cross reference to the IEC 62439-2	YES	Optional; mandatory if MRP is supported
Annex X	Maintaining statistic counters for Ethernet	YES	—

8.2.3.2.4   IO supervisor

See 8.2.3.2.3.

8.2.3.2.5   Options

DHCP according to IETF RFC 2131 is an optional protocol.

DNS is an optional protocol for an IO controller and IO supervisor.

Media redundancy (see 8.1.6).

PTCP is an optional service. If PTCP is supported, the support of both sync master and redundant sync master are optional for an IO device. For an IO controller the support of sync master is mandatory and the support of redundant sync master optional.

RT_Class_UDP is optional.

8.2.4   Performance indicator selection

8.2.4.1   Performance indicator overview

Table 104 specifies the relevant performance indicators.

Table 104 – CP 3/4, CP 3/5 and CP 3/6: performance indicator overview

Performance indicator	Applicable	Constraints
Delivery time	Yes	—
Number of end-stations	Yes	—
Basic network topology	Yes	—
Number of switches between end-stations	Yes	—
Throughput RTE	Yes	—
Non-RTE bandwidth	Yes	—
Time synchronization accuracy	Yes	—
Non-time-based synchronization accuracy	—	—
Redundancy recovery time	Yes	—

8.2.4.2   Performance indicator dependencies

8.2.4.2.1   Performance indicator dependency matrix

Table 105 specifies the dependencies of the performance indicators.

Table 105 – CP 3/4, CP 3/5 and CP 3/6: performance indicator dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchron. Accuracy	Redundancy recovery time
Delivery time		Yes 8.2.4.2.4	NO	Yes 8.2.4.2.2	Yes 8.2.4.2.3	NO	NO	YES 8.2.4.2.5
Number of end-stations	YES 8.2.4.2.4		NO	NO	NO	NO	NO	NO
Basic network topology	YES 8.2.4.2.6	NO		NO	NO	NO	YES 8.2.4.2.7	YES 8.2.4.2.8
Number of switches between end-stations	YES 8.2.4.2.6	NO	NO		NO	NO	YES 8.2.4.2.7	YES 8.2.4.2.9
Throughput RTE	NO	NO	NO	NO		YES 8.2.4.2.10	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	YES 8.2.4.2.10		NO	NO
Time synchronization accuracy	NO	NO	NO	YES 8.2.4.2.11	NO	NO		NO
Redundancy recovery time	NO	NO	YES 8.2.4.2.8	YES 8.2.4.2.12	NO	NO	NO	

8.2.4.2.2 Delivery time

The performance indicator Delivery time can be calculated by Formula (12).

$$DT = cta_S + ctc + cta_R + SSTs + SSTr + tt \cdot data + cd \cdot clt + \sum_{pd=1}^{NoS} f(pd) \cdot NoS + od \qquad (12)$$

where

DT	is the Delivery time;
cta_R	is the application cycle time of the Receiver;
cta_S	is the application cycle time of the Sender;
ctc	is the communication cycle time (see Formula (13)) and shall be equal or longer than MinDeviceInterval;
$STTs$	is the sender stack traversal time;
$STTr$	is the receiver stack traversal time;
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s).
$data$	is the complete Ethernet frame;
cd	is the cable delay (see attribute CableDelayLocal in IEC 61158–5–10);
clt	is the total cable length;
pd	is the propagation delay (see Formula (14));
NoS	is the number of switches;
od	is any other delays, e. g. signal forwarding in a ring.

The communication cycle time can be calculated by Formula (13).

$$ctc = SCF \times RR \times 31,25\mu s \tag{13}$$

where

SCF	is the attribute *SendClockFactor* (see IEC 61158–5–10, Send Clock Factor);
RR	is the attribute *ReductionRatio* (see IEC 61158–5–10, Reduction Ration).

The propagation delay pd can be calculated by Formula (14).

$$pd = Queue\_delay + Phy\_R\_delay + Phy\_S\_delay + MAC\_delay \tag{14}$$

where

Queue_delay	is the Queue delay in a switch;
Phy_R_delay	is the PHY delay on receiver side;
Phy_S_delay	is the PHY delay on sender side;
MAC_delay	is the delay on MAC layer.

Figure 5 represents the calculation basis for delivery time and throughput RTE and shows the logical position where some of the parameter occur.
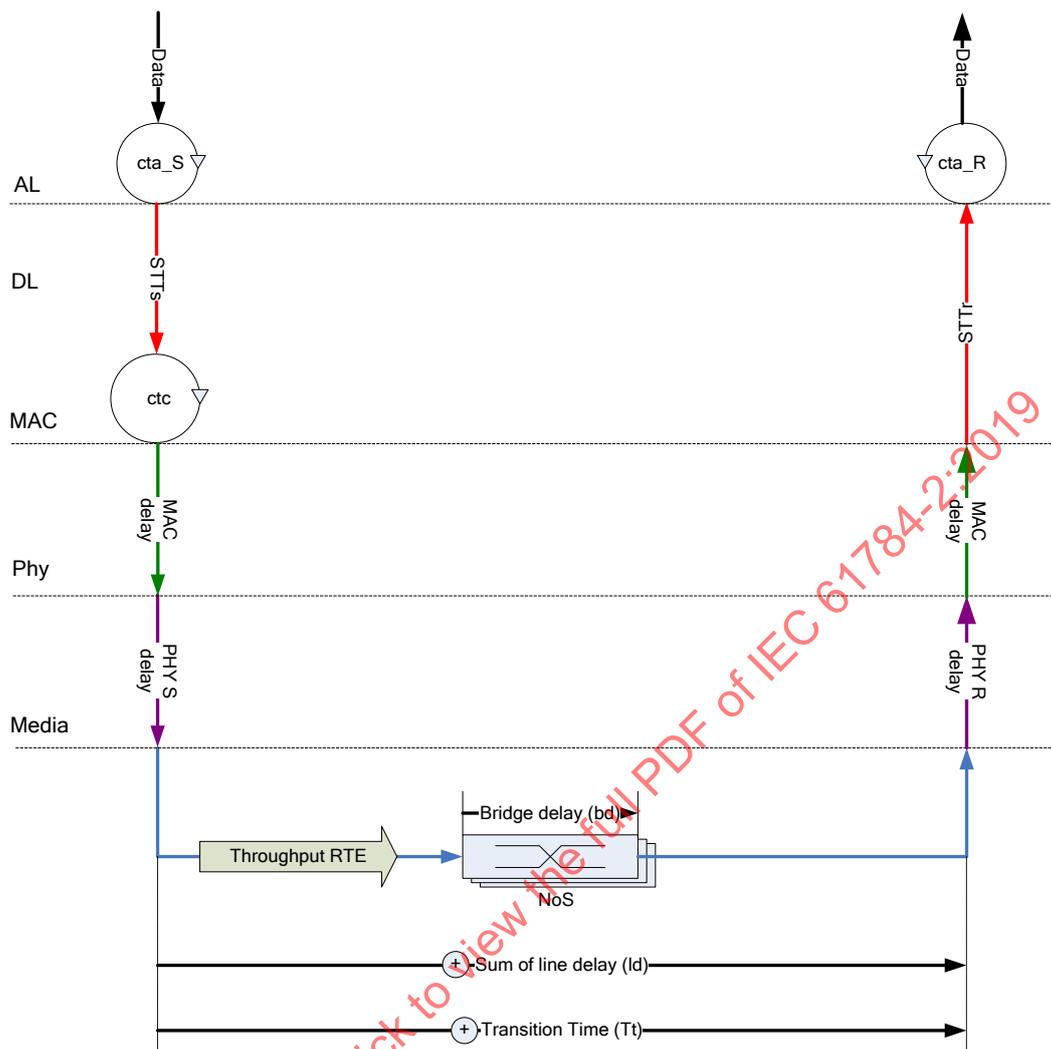
Figure 5 – Calculation basis for delivery time and throughput RTE

8.2.4.2.3 Delivery time dependency on throughput RTE

RTE throughput defines the amount of data within one ctc. Formula (15) specifies the dependencies to various parameters.

If data_request > data_RTE then (15)

– to enlarge throughput RTE
  • ctc constant as long as max throughput RTE could be enlarged to transmit data_request
  • enlarge ctc additionally as much as needed so that max throughput RTE could be enlarged to transmit data_request
– use of multiple ctc

where

data_request   is the requested throughput RTE;

data_RTE   is the actual throughput RTE,

ctc   is the communication cycle time (see Formula (13) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval.

The parameter ctc and data are used in 8.2.4.2.2 to calculate delivery time.

8.2.4.2.4   Delivery time dependency on Number of end-stations

Number of end-stations influences the length of data within one ctc.

The parameter data is used in 8.2.4.2.2 to calculate Delivery time.

8.2.4.2.5   Delivery time dependency on Redundancy recovery time

NoS shall be set to the worst case value of all switches on the configured paths in a redundant topology.

The parameter NoS is used in 8.2.4.2.2 to calculate Delivery time.

8.2.4.2.6   Basic network topology dependency on Delivery time

If the delivery time in a daisy-chain or ring topology exceeds the bounded delivery time then the Basic network topology is to set to a hierarchical star.

8.2.4.2.7   Basic network topology dependency on Time synchronization accuracy

If the Time synchronization accuracy in a daisy-chain or ring topology exceeds the bounded Time synchronization accuracy then the Basic network topology is to set to a hierarchical star.

8.2.4.2.8   Basic network topology dependency on Redundancy recovery time

If redundancy recovery time allows the use of rapid spanning tree algorithm and protocol (RSTP according to IEEE 802.1Q) then no dependencies exist;

Redundancy recovery time of Media redundancy requires ring topology.

For RED_CLASS_1 and RED_CLASS_3, ring ports shall comply to Media Class wired and fiber optic according to 8.2.1.1. The data rate of both ring ports shall be at least 100 Mbit/s and full duplex mode shall be used for both ring ports.

For RED_CLASS_1 the active redundancy manager defines with its parameter set the recovery time of a ring.

The traffic load in the ring and the interconnection shall be less than 90 %.

For RED_CLASS_1 and RED_CLASS_3 Table 106, Table 107, Table 108, and Table 109 specifies the consistent set of parameter for a ring recovery time of 200 ms.

Table 106 – Manager (MRM) parameters

Parameter	Value	Comment
MRP_TOPchgT	10 ms	IEC 61158–6–10
MRP_TOPNRmax	3	IEC 61158–6–10
MRP_TSTshortT	10 ms	IEC 61158–6–10
MRP_TSTdefaultT	20 ms	IEC 61158–6–10
MRP_TSTNRmax	3	IEC 61158–6–10

Table 107 specifies the parameter set for media redundancy clients.

Table 107 – Client (MRC) parameters

Parameter	Value	Comment
MRP_LNKdownT	20 ms	IEC 61158–6–10
MRP_LNKupT	20 ms	IEC 61158–6–10
MRP_LNKNRmax	4	IEC 61158–6–10

Table 108 – Manager (MIM) parameters

Parameter	Value	Comment
MRPIC_TOPchgT	10 ms	IEC 61158–6–10
MRPIC_TOPNRmax	3	IEC 61158–6–10
MRPIC_LinkStatusChangeT	20 ms	IEC 61158–6–10
MRPIC_LinkStatusNRmax	8	IEC 61158–6–10

Table 109 – Client (MIC) parameters

Parameter	Value	Comment
MRPIC_LNKdownT	20 ms	IEC 61158–6–10
MRPIC_LNKupT	20 ms	IEC 61158–6–10
MRPIC_LNKNRmax	4	IEC 61158–6–10

8.2.4.2.9 NoS dependency on Redundancy recovery time

The time to detect the failure is dependent on the NoS.

8.2.4.2.10 Throughput RTE dependency on non-RTE bandwidth

The throughput RTE can be calculated by Formula (16).

$$Throughput\_RTE = (100\% - NonRTE - protocolRTE) \cdot EthernetDataRate/8 \qquad (16)$$

where

Throughput_RTE	is the throughput RTE in octets/s;
protocolRTE	is the percentage of protocol time, see Formula (17);
NonRTE	is the percentage of non-RTE bandwidth;
EthernetDataRate	is the Ethernet data rate of the network.

The protocolRTE can be calculated by Formula (17).

$$protocolRTE = f_{complex}\left(endStations, data, Time_{synchron_{accuracy}}, RM, \ldots\right) \qquad (17)$$

where

endStations	is the number of end-stations;
data	is the complete Ethernet frame in octets,
Time_synchron_accuracy	is the time synchronization accuracy;
RM	is the time needed for management functions to support redundancy.

8.2.4.2.11   Time synchronization accuracy dependency on NoS

Time synchronization accuracy using up to 20 NoS.

8.2.4.2.12   Redundancy recovery time dependency on NoS

The time to detect the failure is dependent on the NoS.

8.2.4.3   Consistent set of performance indicators

Table 110 specifies the consistent set of performance indicators using a network bandwidth of 100 Mbit/s, wired or fiber optic. The values are based on the values given in Table 111 and the methods or algorithm given in 8.2.4.2. This consistent set of performance indicators shall be tested for devices (not wireless) that claim compliance with CP 3/4.

Table 110 – CP 3/4: Consistent set of PI for MinDeviceInterval=128 ms

Performance indicator	Value	Constraints
Delivery time	128 ms watch dog factor × 128 ms	Without failure Frames lost; (See 8.1.4.2, MinDeviceInterval = 128 ms)
Number of end-stations	60	Data is assumed to be a 68 octets Ethernet frame to receive from and send to all end-stations
Number of switches between end-stations	10	—
Throughput RTE	2 324 706 octet/s	—
Non-RTE bandwidth	23,5 %	100 Mbit/s and related to 1 ms. Any ISO/IEC/IEEE 8802-3 frames supported.
Time synchronization accuracy [c]	< 100 µs < 1 µs	Synchronization of local time Synchronization of synchronous application
Redundancy recovery time [c]	0 ms < 200 ms < 384 ms < 200 ms	RT_CLASS_1 [a]: single failure RTA[b] retries = 3; RTA timeout factor = 100 ms RT_CLASS_1 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 128 ms RTA [b] retries = 3; RTA [b] timeout factor = 100 ms
[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.		
[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4.2 of IEC 61158–5–10.		
[c] Optional		

Table 111 – CP 3/4: Assumed values for consistent set of PI calculation

Symbol	Definition	Value
cd	is the cable delay (see parameter cable_delay in IEC 61158–6–10)	5 ns
clt	is the total cable length	100 m
cta_R	is the application cycle time of the Receiver	1 µs
cta_S	is the application cycle time of the Sender	1 µs
ctc	is the communication cycle time (see Formula (13) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval = 128 ms	128 ms
data	is the complete Ethernet frame	68 octets
EthernetDataRate	is the Ethernet data rate of the network	Mbit/s
MAC_delay	is the delay on MAC layer	1 µs
NonRTE	is the percentage of non-RTE bandwidth	%
od	is any other delays, e. g. signal forwarding in a ring	0 s
pd	is the propagation delay (see Formula (14) in 8.2.4.2.2)	—
Phy_R_delay	is the PHY delay on receiver side	300 ns
Phy_S_delay	is the PHY delay on sender side	300 ns
protocolRTE	is the percentage of protocol time (see Formula (17) in 8.2.4.2.10)	50 %
Queue_delay	is the Queue delay in a switch	0 s
RedundancyManagement	is the time needed for management functions to support redundancy	0 s
STTr	is the receiver stack traversal time	0 s
STTs	is the sender stack traversal time	0 s
Time_synchron_accuracy	is the time synchronization accuracy	0 s
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s)	80 ns
SCF	See IEC 61158–5–10, 8.3.10.4.2	32
RR	See IEC 61158–5–10, 8.3.10.4.2	128

8.3 Profile 3/5

8.3.1 Physical layer

The physical layer shall be according to ISO/IEC/IEEE 8802-3.

The data rate shall be at least 100 Mbit/s and full-duplex mode shall be used at least for one port.

8.3.2 Data link layer

The data link layer shall be according to ISO/IEC/IEEE 8802-3, IEEE 802.1AB, and IEEE 802.1Q.

From the various optional Management Information Bases (MIBs) at least the LLDP MIB (see IEEE 802.1AB) and IETF RFC 1213-MIB (MIB-2) are required.

The local injected non real time traffic of each node should be limited per millisecond according to Table 99 to avoid a network overload.

8.3.3 Application layer

8.3.3.1 AL service selection

8.3.3.1.1 IO device

Application layer services for an IO device are defined in IEC 61158–5–10. Table 112 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 112 – CP 3/5: AL service selection for an IO device

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Concepts	YES	—
5	Data type ASE	YES	—
6	Communication model for common services	—	—
6.1	Concepts	YES	—
6.2	ASE data types	YES	—
6.3	Application Service Elements	—	—
6.3.1	Remote procedure call ASE	YES	—
6.3.2	Domain name system ASE	YES	Optional
6.3.3	Simple network management ASE	YES	—
6.3.4	IP suite ASE	YES	ICMP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.5	Real time cyclic ASE	YES	RT_CLASS_UDP is optional
6.3.6	Real time acyclic ASE	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.7	Discovery and basic configuration ASE	YES	—
6.3.8	Dynamic host configuration ASE	YES	Optional
6.3.9	IEEE 802.1AB ASE	YES	n.a. for wireless media
6.3.10	Media redundancy ASE	YES	See 8.1.6, n.a. for wireless media
6.3.11	Precision time control ASE	YES	Optional
6.3.12	IEEE 802.1AS ASE	YES	Optional
6.3.13	Virtual Bridges ASE	YES	n.a. for wireless media
6.3.14	MAC Bridges ASE	YES	Only applicable if a network component is integrated.
6.3.15	Fragmentation ASE	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
6.3.16	IEEE 802.3 ASE	YES	n.a. for wireless media
6.3.17	Common DL mapping ASE	—	—
6.3.17.1	Overview	YES	—
6.3.17.2	DL Mapping class specification	YES	—
6.3.17.3	DL Mapping service specification	—	—
6.3.17.3.1	P Data	YES	Optional; mandatory if Precision Time Control ASE is supported

Clause	Header	Presence	Constraints
6.3.17.3.2	N Data	YES	—
6.3.17.3.3	A Data	YES	—
6.3.17.3.4	C Data	YES	—
7	Communication model for decentralized periphery	—	—
7.1	Concepts	YES	—
7.2	ASE data types	YES	—
7.3	ASEs	—	—
7.3.1	AR ASE	YES	—
7.3.2	Real Identification ASE	YES	—
7.3.3	Communication Interface Management ASE	YES	—
7.3.4	Diagnosis ASE	YES	—
7.3.5	PE ASE	YES	Optional
7.3.6	LogBook ASE	YES	—
7.3.7	RS ASE	YES	Optional
7.3.8	Time ASE	YES	Optional
7.4	Application characteristics	YES	—
7.5	Summary of FAL services	—	—
7.5.1	IO device	YES	—
7.5.2	IO controller	NO	—
7.5.3	IO Supervisor	NO	—
Annex A	Device instances	YES	—
Annex B	Components of an Ethernet interface	Partial	Used when applicable
Annex C	Scheme of MAC address assignment	YES	—
Annex D	Measurement of the fast startup time	YES	—
Annex E	Dynamic Frame Packing	YES	Optional
Annex F	Precondition for Diagnosis	YES	—
—	Bibliography	YES	—

8.3.3.1.2 Network component

Application layer services for a network component are defined in IEC 61158–5–10. Table 112 holds the application layer service selections from IEC 61158–5–10 for this profile.

The requirements from 8.1.11.4 apply.

8.3.3.1.3 IO controller

Application layer services for an IO controller are defined in IEC 61158–5–10. Table 112 changed by the content of Table 113 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 113 – CP 3/5: Additional AL service selection for an IO controller

Clause	Header	Presence	Constraints
7.1.4.2	IO controller	YES	Optional
7.1.4.3	IO supervisor	NO	—
7.1.4.4	IO parameter server	NO	—
7.1.4.5	IO device	NO	—
7.3.6	LogBook Data ASE	YES	Optional

8.3.3.1.4   IO supervisor

See 8.3.3.1.3.

8.3.3.1.5   Options

DHCP according to IETF RFC 2131 is an optional service.

DNS is an optional service for an IO controller and IO supervisor.

MRP is an optional service.

PTCP is an optional service.

8.3.3.2   AL protocol selection

8.3.3.2.1   IO device

Application layer protocols for an IO device are defined in IEC 61158–6–10. Table 114 holds the application layer protocol selections from IEC 61158–6–10 for this profile.

Table 114 – CP 3/5: AL protocol selection for an IO device and Network component

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviated terms, symbols and conventions	Partial	Used if needed
4	Application layer protocol specification for common protocols	—	—
4.1	FAL syntax description	YES	—
4.2	Transfer syntax	YES	—
4.2.1	Coding of basic data types	Partial	Used if needed
4.2.2	Coding section related to common basic fields	Partial	Used if needed
4.3	Discovery and basic configuration	YES	—
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real time cyclic	YES	RT_CLASS_UDP is optional

Clause	Header	Presence	Constraints
4.8	Real time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	—
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	Bridges and End Stations	YES	—
4.13	IP suite	—	—
4.13.1	Overview	YES	—
4.13.2	IP/UDP syntax description	YES	—
4.13.3	IP/UDP transfer syntax	YES	—
4.13.4	ARP	—	—
4.13.4.1	General	YES	—
4.13.4.2	ARP Cache Control Machine	YES	Optional
4.14	Domain name system	YES	Optional
4.15	Dynamic host configuration	YES	Optional
4.16	Simple network management	YES	—
4.17	Common DLL Mapping Protocol Machines	YES	—
4.18	Additional definitions	YES	—
5	Application layer protocol specification for decentralized periphery	—	—
5.1	FAL syntax description	YES	—
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	—
5.5	FAL Service Protocol Machines	YES	—
5.5.1	Overview	YES	—
5.5.2	FAL Service Protocol Machine Device	YES	—
5.5.3	FAL Service Protocol Machine Controller	NO	—
5.6	Application Relationship Protocol Machines	—	—
5.6.1	Alarm Protocol Machine Initiator	YES	—
5.6.2	Alarm Protocol Machine Responder	YES	—
5.6.3	Device	YES	—
5.6.4	Controller	NO	—
5.7	DLL Mapping Protocol Machines	YES	—
Annex A	Unified establishing of an AR for all RT classes	YES	—
Annex B	Compatible establishing of an AR	YES	—
Annex C	Establishing of a device access AR	YES	—
Annex D	Establishing of an AR (accelerated procedure)	YES	—
Annex E	Establishing of an AR (fast startup procedure)	YES	—
Annex F	Example of the upload, storage and retrieval procedure	YES	—
Annex G	OSI reference model layers	YES	—
Annex H	Overview of the IO controller and the IO device state machines	YES	—

Clause	Header	Presence	Constraints
Annex I	Priority regeneration	YES	—
Annex J	Overview of the PTCP synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwidth usage	YES	—
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_3 is supported
Annex M	Time constraints for the forwarding of a frame	YES	—
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 μs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	—
Annex S	Example of a PrmBegin, PrmEnd and ApplRdy sequence	YES	—
Annex T	List of supported MIBs	YES	Optional
Annex U	Structure and content of BLOB	YES	If needed
Annex V	LLDP EXT MIB	YES	Optional
Annex W	Cross reference to the IEC 62439-2	YES	Optional; mandatory if MRP is supported
Annex X	Maintaining statistic counters for Ethernet	YES	—

8.3.3.2.2   Network component

Application layer protocols for a network component are defined in IEC 61158–6–10. Table 114 specifies the clauses included in this profile.

The requirements from 8.1.11.4 apply.

8.3.3.2.3   IO controller

Application layer protocols for an IO controller are defined in IEC 61158–6–10. Table 115 specifies the clauses included in this profile.

Table 115 – CP 3/5: AL protocol selection for an IO controller

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviated terms, symbols and conventions	Partial	Used if needed
4	Application layer protocol specification for common protocols	—	—
4.1	FAL syntax description	YES	—
4.2	Transfer syntax	YES	—

Clause	Header	Presence	Constraints
4.2.1	Coding of basic data types	Partial	Used if needed
4.2.2	Coding section related to common basic fields	Partial	Used if needed
4.3	Discovery and basic configuration	YES	Support of the DCP function "ResetToFactory" recommended for IO controller
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	—
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	Bridges and End Stations	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	IP suite	—	—
4.13.1	Overview	YES	—
4.13.2	IP/UDP syntax description	YES	—
4.13.3	IP/UDP transfer syntax	YES	—
4.13.4	ARP	—	—
4.13.4.1	General	YES	—
4.13.4.2	ARP Cache Control Machine	YES	Optional
4.14	Domain name system	YES	Optional
4.15	Dynamic host configuration	YES	Optional
4.16	Simple network management	YES	—
4.17	Common DLL Mapping Protocol Machines	YES	—
4.18	Additional definitions	YES	—
5	Application layer protocol specification for decentralized periphery	—	—
5.1	FAL syntax description	YES	—
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	—
5.5	FAL Service Protocol Machines	YES	—
5.5.1	Overview	YES	—
5.5.2	FAL Service Protocol Machine Device	NO	—
5.5.3	FAL Service Protocol Machine Controller	YES	—
5.6	Application Relationship Protocol Machines	—	—
5.6.1	Alarm Protocol Machine Initiator	YES	—
5.6.2	Alarm Protocol Machine Responder	YES	—
5.6.3	Device	NO	—
5.6.4	Controller	YES	—
5.7	DLL Mapping Protocol Machines	YES	—

Clause	Header	Presence	Constraints
Annex A	Unified establishing of an AR for all RT classes	YES	—
Annex B	Compatible establishing of an AR	YES	—
Annex C	Establishing of a device access AR	YES	—
Annex D	Establishing of an AR (accelerated procedure)	YES	—
Annex E	Establishing of an AR (fast startup procedure)	YES	—
Annex F	Example of the upload, storage and retrieval procedure	YES	—
Annex G	OSI reference model layers	YES	—
Annex H	Overview of the IO controller and the IO device state machines	YES	—
Annex I	Priority regeneration	YES	—
Annex J	Overview of the PTCP synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwidth usage	YES	—
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_3 is supported
Annex M	Time constraints for the forwarding of a frame	YES	—
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	—
Annex S	Example of a PrmBegin, PrmEnd and ApplRdy sequence	YES	—
Annex T	List of supported MIBs	YES	Optional
Annex U	Structure and content of BLOB	YES	If needed
Annex V	LLDP EXT MIB	YES	Optional
Annex W	Cross reference to the IEC 62439-2	YES	Optional; mandatory if MRP is supported
Annex X	Maintaining statistic counters for Ethernet	YES	—

8.3.3.2.4   IO supervisor

See 8.2.3.1.3.

8.3.3.2.5   Options

DHCP according to IETF RFC 2131 is an optional protocol.

DNS is an optional protocol for an IO controller and IO supervisor.

Media redundancy (see 8.1.6).

PTCP is an optional service.

8.3.4 Performance indicator selection

8.3.4.1 Performance indicator overview

8.2.4.1 applies.

8.3.4.2 Performance indicator dependencies

8.2.4.2 applies.

8.3.4.3 Consistent set of performance indicators

Table 116 specifies the consistent set of performance indicators using a network bandwidth of 100 Mbit/s, wired or fiber optic. The values are based of the values given in Table 107 and the methods or algorithm given in 8.2.4.2. This consistent set of performance indicators shall be tested for devices (not for wireless) that claim compliance with CP 3/5.

Table 116 – CP 3/5: Consistent set of PI for MinDeviceInterval=128 ms

Performance indicator	Value	Constraints
Delivery time	128 ms watch dog factor × 128 ms	Without failure Frames lost; (See 8.1.4.2, MinDeviceInterval = 128 ms)
Number of end-stations	60	Data is assumed to be a 68 octets Ethernet frame to receive from and send to all end-stations
Number of switches between end-stations	10	—
Throughput RTE	2 324 706 octet/s	—
Non-RTE bandwidth	23,5 %	100 Mbit/s and related to 1 ms. Any ISO/IEC/IEEE 8802-3 frames supported.
Time synchronization accuracy[c]	< 100 μs	Synchronization of local time
	< 1 μs	Synchronization of synchronous application
Redundancy recovery time[c]	0 ms	RT_CLASS_1 [a]: single failure
	< 200 ms	RTA [b] retries = 3; RTA timeout factor = 100 ms
	< 384 ms	RT_CLASS_1 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 128 ms
	< 200 ms	RTA [b] retries = 3; RTA [b] timeout factor = 100 ms
[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.		
[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4.2 of IEC 61158–5–10.		
[c] Optional		

Table 117 – CP 3/5: Assumed values for consistent set of PI calculation

Symbol	Definition	Value
cd	is the cable delay (see parameter cable_delay in IEC 61158–6–10)	5 ns
clt	is the total cable length	100 m
cta_R	is the application cycle time of the Receiver	1 µs
cta_S	is the application cycle time of the Sender	1 µs
ctc	is the communication cycle time (see Formula (13) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval = 128 ms	128 ms
data	is the complete Ethernet frame	68 octets
EthernetDataRate	is the Ethernet data rate of the network	Mbit/s
MAC_delay	is the delay on MAC layer	1 µs
NonRTE	is the percentage of non-RTE bandwidth	%
od	is any other delays, e. g. signal forwarding in a ring	0 s
pd	is the propagation delay (see Formula (14) in 8.2.4.2.2)	—
Phy_R_delay	is the PHY delay on receiver side	300 ns
Phy_S_delay	is the PHY delay on sender side	300 ns
protocolRTE	is the percentage of protocol time (see Formula (17) in 8.2.4.2.10)	50 %
Queue_delay	is the Queue delay in a switch	0 s
RedundancyManagement	is the time needed for management functions to support redundancy	0 s
STTr	is the receiver stack traversal time	0 s
STTs	is the sender stack traversal time	0 s
Time_synchron_accuracy	is the time synchronization accuracy	0 s
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s)	80 ns
SCF	See IEC 61158–5–10, 8.3.10.4.2	32
RR	See IEC 61158–5–10, 8.3.10.4.2	128

8.4   Profile 3/6

8.4.1   Physical layer

The physical layer shall be according to ISO/IEC/IEEE 8802-3.

The data rate shall be at least 100 Mbit/s and full-duplex mode shall be used at least for one port.

8.4.2   Data link layer

The data link layer shall be according to ISO/IEC/IEEE 8802-3, IEEE 802.1AB, and IEEE 802.1Q.

From the various optional Management Information Bases (MIBs) at least the LLDP MIB (see IEEE 802.1AB) and IETF RFC 1213-MIB (MIB-2) are required.

The local injected non real time traffic of each node should be limited per millisecond according to Table 99 to avoid a network overload.

8.4.3 Application layer

8.4.3.1 AL service selection

8.4.3.1.1 IO device

Application layer services for an IO device are defined in IEC 61158–5–10. Table 118 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 118 – CP 3/6: AL service selection for an IO device

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviations, symbols and conventions	Partial	Used if needed
4	Concepts	YES	—
5	Data type ASE	YES	—
6	Communication model for common services	—	—
6.1	Concepts	YES	—
6.2	ASE data types	YES	—
6.3	Application Service Elements	—	—
6.3.1	Remote procedure call ASE	YES	—
6.3.2	Domain name system ASE	YES	Optional
6.3.3	Simple network management ASE	YES	—
6.3.4	IP suite ASE	YES	ICMP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.5	Real time cyclic ASE	YES	RT_CLASS_UDP is optional
6.3.6	Real time acyclic ASE	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
6.3.7	Discovery and basic configuration ASE	YES	—
6.3.8	Dynamic host configuration ASE	YES	Optional
6.3.9	IEEE 802.1AB ASE	YES	n.a. for wireless media
6.3.10	Media redundancy ASE	YES	See 8.1.6, n.a. for wireless media
6.3.11	Precision time control ASE	YES	—
6.3.12	IEEE 802.1AS ASE	YES	Optional
6.3.13	Virtual Bridges ASE	YES	n.a. for wireless media
6.3.14	MAC Bridges ASE	YES	Only applicable if a network component is integrated.
6.3.15	Fragmentation ASE	YES	Optional; mandatory if send clocks lower than 250 μs are supported.
6.3.16	IEEE 802.3 ASE	YES	n.a. for wireless media
6.3.17	Common DL mapping ASE	—	—
6.3.17.1	Overview	YES	—
6.3.17.2	DL Mapping class specification	YES	—
6.3.17.3	DL Mapping service specification	—	—
6.3.17.3.1	P Data	YES	Optional; mandatory if Precision Time Control ASE is supported

Clause	Header	Presence	Constraints
6.3.17.3.2	N Data	YES	—
6.3.17.3.3	A Data	YES	—
6.3.17.3.4	C Data	YES	—
7	Communication model for decentralized periphery	—	—
7.1	Concepts	YES	—
7.2	ASE data types	YES	—
7.3	ASEs	—	—
7.3.1	AR ASE	YES	—
7.3.2	Real Identification ASE	YES	—
7.3.3	Communication Interface Management ASE	YES	—
7.3.4	Diagnosis ASE	YES	—
7.3.5	PE ASE	YES	Optional
7.3.6	LogBook ASE	YES	—
7.3.7	RS ASE	YES	Optional
7.3.8	Time ASE	YES	Optional
7.4	Application characteristics	YES	—
7.5	Summary of FAL services	—	—
7.5.1	IO device	YES	—
7.5.2	IO controller	NO	—
7.5.3	IO Supervisor	NO	—
Annex A	Device instances	YES	—
Annex B	Components of an Ethernet interface	Partial	Used when applicable
Annex C	Scheme of MAC address assignment	YES	—
Annex D	Measurement of the fast startup time	YES	—
Annex E	Dynamic Frame Packing	YES	Optional
Annex F	Precondition for Diagnosis	YES	—
—	Bibliography	YES	—

8.4.3.1.2 Network component

Application layer services for a network component are defined in IEC 61158–5–10. Table 118 holds the application layer service selections from IEC 61158–5–10 for this profile.

The requirements from 8.1.11.4 apply.

8.4.3.1.3 IO controller

Application layer services for an IO controller are defined in IEC 61158–5–10. Table 118 changed by the content of Table 119 holds the application layer service selections from IEC 61158–5–10 for this profile.

Table 119 – CP 3/6: Additional AL service selection for an IO controller

Clause	Header	Presence	Constraints
7.1.4.2	IO controller	YES	Optional
7.1.4.3	IO supervisor	NO	—
7.1.4.4	IO parameter server	NO	—
7.1.4.5	IO device	NO	—
7.3.6	LogBook Data ASE	YES	Optional

8.4.3.1.4 IO supervisor

Not applicable.

8.4.3.1.5 Options

DHCP according to IETF RFC 2131 is an optional service.

DNS is an optional service for an IO controller and IO supervisor.

8.4.3.2 AL protocol selection

8.4.3.2.1 IO device

Application layer protocols for an IO device are defined in IEC 61158–6–10. Table 120 holds the application layer protocol selections from IEC 61158–6–10 for this profile.

Table 120 – CP 3/6: AL protocol selection for an IO device and network component

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviated terms, symbols and conventions	Partial	Used if needed
4	Application layer protocol specification for common protocols	—	—
4.1	FAL syntax description	YES	—
4.2	Transfer syntax	YES	—
4.2.1	Coding of basic data types	Partial	Used if needed
4.2.2	Coding section related to common basic fields	Partial	Used if needed
4.3	Discovery and basic configuration	YES	—
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.

Clause	Header	Presence	Constraints
4.10	Remote procedure call	YES	—
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	Bridges and End Stations	YES	—
4.13	IP suite	—	—
4.13.1	Overview	YES	—
4.13.2	IP/UDP syntax description	YES	—
4.13.3	IP/UDP transfer syntax	YES	—
4.13.4	ARP	—	—
4.13.4.1	General	YES	—
4.13.4.2	ARP Cache Control Machine	YES	Optional
4.14	Domain name system	YES	Optional
4.15	Dynamic host configuration	YES	Optional
4.16	Simple network management	YES	—
4.17	Common DLL Mapping Protocol Machines	YES	—
4.18	Additional definitions	YES	—
5	Application layer protocol specification for decentralized periphery	—	—
5.1	FAL syntax description	YES	—
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	—
5.5	FAL Service Protocol Machines	YES	—
5.5.1	Overview	YES	—
5.5.2	FAL Service Protocol Machine Device	YES	—
5.5.3	FAL Service Protocol Machine Controller	NO	—
5.6	Application Relationship Protocol Machines	—	—
5.6.1	Alarm Protocol Machine Initiator	YES	—
5.6.2	Alarm Protocol Machine Responder	YES	—
5.6.3	Device	YES	—
5.6.4	Controller	NO	—
5.7	DLL Mapping Protocol Machines	YES	—
Annex A	Unified establishing of an AR for all RT classes	YES	—
Annex B	Compatible establishing of an AR	YES	—
Annex C	Establishing of a device access AR	YES	—
Annex D	Establishing of an AR (accelerated procedure)	YES	—
Annex E	Establishing of an AR (fast startup procedure)	YES	—
Annex F	Example of the upload, storage and retrieval procedure	YES	—
Annex G	OSI reference model layers	YES	—
Annex H	Overview of the IO controller and the IO device state machines	YES	—
Annex I	Priority regeneration	YES	—
Annex J	Overview of the PTCP synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwidth usage	YES	—

Clause	Header	Presence	Constraints
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_3 is supported
Annex M	Time constraints for the forwarding of a frame	YES	—
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	—
Annex S	Example of a PrmBegin, PrmEnd and ApplRdy sequence	YES	—
Annex T	List of supported MIBs	YES	Optional
Annex U	Structure and content of BLOB	YES	If needed
Annex V	LLDP EXT MIB	YES	Optional
Annex W	Cross reference to the IEC 62439-2	YES	Optional; mandatory if MRP is supported
Annex X	Maintaining statistic counters for Ethernet	YES	—

8.4.3.2.2 Network component

Application layer protocols for a network component are defined in IEC 61158–6–10. Table 120 specifies the clauses included in this profile.

A 100 Mbit/s switch shall support buffering of all data according to 8.1.11.4. This shall be applicable with 100 % bandwidth concurrent at all ports for frames with the smallest frame size.

8.4.3.2.3 IO controller

Application layer protocols for an IO controller are defined in IEC 61158–6–10. Table 121 specifies the clauses included in this profile.

Table 121 – CP 3/6: AL protocol selection for an IO controller

Clause	Header	Presence	Constraints
—	FOREWORD	YES	—
—	INTRODUCTION	YES	—
1	Scope	YES	—
2	Normative references	Partial	Used if needed
3	Terms, definitions, abbreviated terms, symbols and conventions	Partial	Used if needed
4	Application layer protocol specification for common protocols	—	—
4.1	FAL syntax description	YES	—
4.2	Transfer syntax	YES	—
4.2.1	Coding of basic data types	Partial	Used if needed
4.2.2	Coding section related to common basic fields	Partial	Used if needed

Clause	Header	Presence	Constraints
4.3	Discovery and basic configuration	YES	Support of the DCP function "ResetToFactory" recommended for IO controller
4.4	Precision working time control	YES	Optional, n.a. for wireless media
4.5	Time synchronization	YES	Optional
4.6	Media redundancy	YES	See 8.1.6, n.a. for wireless media
4.7	Real time cyclic	YES	RT_CLASS_UDP is optional
4.8	Real time acyclic	YES	RTA_CLASS_UDP is optional; mandatory if RT_CLASS_UDP is supported.
4.9	Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
4.10	Remote procedure call	YES	—
4.11	Link layer discovery	YES	n.a. for wireless media
4.12	Bridges and End Stations	YES	Only applicable if a network component is integrated. Otherwise only PortStateChanged and SetPortState are used.
4.13	IP suite	—	—
4.13.1	Overview	YES	—
4.13.2	IP/UDP syntax description	YES	—
4.13.3	IP/UDP transfer syntax	YES	—
4.13.4	ARP	—	—
4.13.4.1	General	YES	—
4.13.4.2	ARP Cache Control Machine	YES	Optional
4.14	Domain name system	YES	Optional
4.15	Dynamic host configuration	YES	Optional
4.16	Simple network management	YES	—
4.17	Common DLL Mapping Protocol Machines	YES	—
4.18	Additional definitions	YES	—
5	Application layer protocol specification for decentralized periphery	—	—
5.1	FAL syntax description	YES	—
5.2	Transfer syntax	YES	When applicable
5.3	FAL protocol state machines	YES	When applicable
5.4	AP-Context state machine	YES	—
5.5	FAL Service Protocol Machines	YES	—
5.5.1	Overview	YES	—
5.5.2	FAL Service Protocol Machine Device	NO	—
5.5.3	FAL Service Protocol Machine Controller	YES	—
5.6	Application Relationship Protocol Machines	—	—
5.6.1	Alarm Protocol Machine Initiator	YES	—
5.6.2	Alarm Protocol Machine Responder	YES	—
5.6.3	Device	NO	—
5.6.4	Controller	YES	—
5.7	DLL Mapping Protocol Machines	YES	—
Annex A	Unified establishing of an AR for all RT classes	YES	—
Annex B	Compatible establishing of an AR	YES	—

Clause	Header	Presence	Constraints
Annex C	Establishing of a device access AR	YES	—
Annex D	Establishing of an AR (accelerated procedure)	YES	—
Annex E	Establishing of an AR (fast startup procedure)	YES	—
Annex F	Example of the upload, storage and retrieval procedure	YES	—
Annex G	OSI reference model layers	YES	—
Annex H	Overview of the IO controller and the IO device state machines	YES	—
Annex I	Priority regeneration	YES	—
Annex J	Overview of the PTCP synchronization master hierarchy	YES	Optional; mandatory if Precision time control is supported
Annex K	Optimization of bandwidth usage	YES	—
Annex L	Time constraints for bandwidth allocation	YES	Optional; mandatory if RT_CLASS_3 is supported
Annex M	Time constraints for the forwarding of a frame	YES	—
Annex N	Principle of dynamic frame packing	YES	Optional
Annex O	Principle of Fragmentation	YES	Optional; mandatory if send clocks lower than 250 µs are supported.
Annex P	MRPD – Principle of seamless media redundancy	YES	Optional; mandatory if RED_CLASS_3 is supported.
Annex Q	Principle of a RED_RELAY without forwarding information in PDIRFrameData	YES	Optional
Annex R	Optimization for fast startup without autonegotiation	YES	—
Annex S	Example of a PrmBegin, PrmEnd and ApplRdy sequence	YES	—
Annex T	List of supported MIBs	YES	Optional
Annex U	Structure and content of BLOB	YES	If needed
Annex V	LLDP EXT MIB	YES	Optional
Annex W	Cross reference to the IEC 62439-2	YES	Optional; mandatory if MRP is supported
Annex X	Maintaining statistic counters for Ethernet	YES	—

8.4.3.2.4   IO supervisor

Not applicable.

8.4.3.2.5   Options

8.4.3.1.5 applies.

8.4.4   Performance indicator selection

8.4.4.1   Performance indicator overview

8.2.4.1 applies.

8.4.4.2   Performance indicator dependencies

8.2.4.2 applies.

8.4.4.3   Consistent set of performance indicators

8.4.4.3.1   MinDeviceInterval=1 ms

Table 122 and Table 123 specifies the consistent set of performance indicators using a network bandwidth of 100 Mbit/s, wired or fiber optic. The values are based of the figures given in Table 124 and the methods or algorithm given in 8.2.4.2. This consistent set of performance indicators shall be tested for devices (not wireless) that claim compliance with CP 3/6.

**Table 122 – CP 3/6: Consistent set of PI for MinDeviceInterval=1 ms
and NumberOfSwitches=20**

Performance indicator	Value	Constraints
Delivery time	1 ms watch dog factor × 1 ms	Without failure Frames lost; (See 8.1.4.2, MinDeviceInterval = 1 ms)
Number of end-stations	60	Using 4 port switches and line topology; a switch is also an end-station
Number of switches between end-stations	20	—
Throughput RTE	3 324 706 octets/s	—
Non-RTE bandwidth	23,5 %	100 Mbit/s and related to 1 ms. Any ISO/IEC/IEEE 8802-3 frames supported.
Time synchronization accuracy	< 100 µs	Synchronization of local time [c]
	< 1 µs	Synchronization of synchronous application
Redundancy recovery time	0 ms < 200 ms	RT_CLASS_3 [a]: single failure RTA [b] retries = 3; RTA timeout factor = 100 ms
	< 3 ms < 200 ms	RT_CLASS_3 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 1 ms RTA [b] retry = 3; RTA time out factor = 100 ms
[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.		
[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4 of IEC 61158–5–10.		
[c] Optional		

**Table 123 – CP 3/6: Consistent set of PI for MinDeviceInterval=1 ms
and NumberOfSwitches=63**

Performance indicator	Value	Constraints
Delivery time	1 ms watch dog factor × 1 ms	Without failure Frames lost; (See 8.1.4.2, MinDeviceInterval = 1 ms)
Number of end-stations	64	Using 2 port switches and line topology; a switch is also an end-station
Number of switches between end-stations	62	—
Throughput RTE	3 546 353 octets/s	—
Non-RTE bandwidth	23 %	100 Mbit/s and related to 1 ms. Any ISO/IEC/IEEE 8802-3 frames supported.
Time synchronization accuracy	< 1 ms	Synchronization of local time [c]
	< 1 µs	Synchronization of synchronous application
Redundancy recovery time	0 ms	RT_CLASS_3 [a]: single failure RTA[b] retries = 3; RTA timeout factor = 100 ms
	< 200 ms	
	< 3 ms	RT_CLASS_3 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 1 ms RTA [b] retry = 3; RTA time out factor = 100 ms
	< 200 ms	

[a]   The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.

[b]   The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4 of IEC 61158–5–10.

[c]   Optional

Table 124 – CP 3/6: Assumed values for consistent set of PI calculation

Symbol	Definition	Value
Cd	is the cable delay (see parameter cable_delay in IEC 61158–6–10)	5 ns
Clt	is the total cable length	100 m
cta_R	is the application cycle time of the Receiver	1 µs
cta_S	is the application cycle time of the Sender	1 µs
Ctc	is the communication cycle time (see Formula (13) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval	1 ms
Data	is the complete Ethernet frame	68 octets
EthernetDataRate	is the Ethernet data rate of the network	Mbit/s
MAC_delay	is the delay on MAC layer	1 µs
NonRTE	is the percentage of non-RTE bandwidth	%
Od	is any other delays, e. g. signal forwarding in a ring	0 s
Pd	is the propagation delay (see Formula (14) in 8.2.4.2.2)	—
Phy_R_delay	is the PHY delay on receiver side	300 ns
Phy_S_delay	is the PHY delay on sender side	300 ns
protocolRTE	is the percentage of protocol time (see Formula (17) in 8.2.4.2.10)	50 %
Queue_delay	is the Queue delay in a switch	0 s

Symbol	Definition	Value
RedundancyManagement	is the time needed for management functions to support redundancy	0 s
STTr	is the receiver stack traversal time	0 s
STTs	is the sender stack traversal time	0 s
Time_synchron_accuracy	is the time synchronization accuracy	1 µs
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s)	80 ns
SCF	See IEC 61158–5–10, 8.3.10.4.2	32
RR	See IEC 61158–5–10, 8.3.10.4.2	1

8.4.4.3.2   MinDeviceInterval=31.25 µs

Table 125 specifies the consistent set of performance indicators using a network bandwidth of 100 Mbit/s, wired or fiber optic. The values are based of the figures given in Table 126 and the methods or algorithm given in 8.2.4.2. This consistent set of performance indicators shall be tested for devices (not wireless) that claim compliance with CP 3/6, form together a DFP group, claim conformance to the apoplication class "high performance" and support the given MinDeviceInterval.

Table 125 – CP 3/6: Consistent set of PI for MinDeviceInterval=31,25 µs and NumberOfSwitches=10

Performance indicator	Value	Constraints
Delivery time	31,25 µs watch dog factor × 31,25 µs	Without failure Frames lost; (See 8.1.4.2, MinDeviceInterval = 31.25 µs)
Number of end-stations	10	Using 2 port switches and line topology; a switch is also an end-station
Number of switches between end-stations	8	—
Throughput RTE	3 264 000 octets/s	—
Non-RTE bandwidth	34,6 %	100 Mbit/s and related to 1 ms. Any ISO/IEC/IEEE 8802-3 frames supported.
Time synchronization accuracy	< 100 µs	Synchronization of local time [c]
	< 1 µs	Synchronization of synchronous application
Redundancy recovery time	0 ms	RT_CLASS_3 [a]: single failure
	< 200 ms	RTA [b] retries = 3; RTA timeout factor = 100 ms
	< 100 µs	RT_CLASS_3 [a]: double failure (line break and surge) watch dog factor = 3; delivery time = 31.25 µs
	< 200 ms	RTA [b] retry = 3; RTA time out factor = 100 ms
[a] The attributes RT_CLASS_x are specified in 8.3.10.4.2 of IEC 61158–5–10.		
[b] The attributes RTA Retries and RTA Timeout Factor are specified in 8.3.10.4 of IEC 61158–5–10.		
[c] Optional		

Table 126 – CP 3/6: Assumed values for consistent set of PI calculation

Symbol	Definition	Value
cd	is the cable delay (see parameter cable_delay in IEC 61158–6–10)	5 ns
clt	is the total cable length	100 m
cta_R	is the application cycle time of the Receiver	1 µs
cta_S	is the application cycle time of the Sender	1 µs
ctc	is the communication cycle time (see Formula (13) in 8.2.4.2.2) and shall be equal or longer than MinDeviceInterval	31.25 µs
data	is the complete Ethernet frame	118 octets
EthernetDataRate	is the Ethernet data rate of the network	Mbit/s
MAC_delay	is the delay on MAC layer	1 µs
NonRTE	is the percentage of non-RTE bandwidth	%
od	is any other delays, e. g. signal forwarding in a ring	0 s
pd	is the propagation delay (see Formula (14) in 8.2.4.2.2)	—
Phy_R_delay	is the PHY delay on receiver side; the maximum value of the application profile "high performance"	210 ns
Phy_S_delay	is the PHY delay on sender side; the maximum value of the application profile "high performance"	90 ns
protocolRTE	is the percentage of protocol time (see Formula (17) in 8.2.4.2.10)	50 %
Queue_delay	is the Queue delay in a switch	0 s
RedundancyManagement	is the time needed for management functions to support redundancy	0 s
STTr	is the receiver stack traversal time	0 s
STTs	is the sender stack traversal time	0 s
Time_synchron_accuracy	is the time synchronization accuracy	1 µs
tt	is the transfer time (80 ns/octet for 100 Mbit/s, 8 ns/octet for 1 Gbit/s)	80 ns
SCF	See IEC 61158–5–10, 8.3.10.4.2	1
RR	See IEC 61158–5–10, 8.3.10.4.2	1

9 Communication Profile Family 4 (P-NET) – RTE communication profiles

9.1 General overview

Communication Profile Family 4 defines profiles based on IEC 61158-2 Type 4, IEC 61158-3-4, IEC 61158-4-4, IEC 61158-5-4 and IEC 61158-6-4, which corresponds to parts of a communication system commonly known as P-NET®[7].

– Profile 4/1 P-NET RS 485

This profile contains AL, DLL and PhL services and protocol references with an IEC 61158 compliant application access. Profile 4/1 is based on ANSI TIA/EIA-485-A, and allows up to 125 devices of normal or simple class to communicate on the same physical link, in half duplex mode.

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[7] P-NET is a trade name of International P-NET User Organisation ApS (IPUO). This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name P-NET. Use of the trade name P-NET requires permission from the trade name holder.

– Profile 4/2 *Void*

– Profile 4/3 P-NET on IP

This profile contains AL and DLL services and protocol references with an IEC 61158 compliant application access. Profile 4/3 is based to ISO/IEC/IEEE 8802-3, and allows up to 125 devices of normal class to communicate on the same logical link, in full-duplex mode.

Profile 4/1 is described in IEC 61784-1, whereas profile 4/3 is described in this document.

9.2 Profile 4/3, P-NET on IP

9.2.1 Physical layer

The physical layer of the P-NET on IP profile is implemented according to ISO/IEC/IEEE 8802-3 or ISO/IEC 8802-11. P-NET devices for this profile shall use a data rate of at least 10 Mbit/s and full-duplex mode.

9.2.2 Data-link layer

9.2.2.1 DLL service selection

Table 127 holds the data-link layer service selections from IEC 61158-3-4 for this profile.

Table 127 – CP 4/3: DLL service selection

Clause	Header	Presence	Constraints
1	Scope and object	YES	–
2	Normative references	Partial	Used if needed
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Data Link Service and concepts	YES	–
5	DL-management Service	–	–
5.1	Scope and inheritance	NO	–
5.2	Facilities of the DL-management service	Partial	Bullets a) and b)
5.3	Model of the DL-management service	YES	–
5.4	Constraints on sequence of primitives	Partial	Only the parts referring to DLM-Set and DLM-Get
5.5	DL-Set	YES	–
5.6	DL-Get	YES	–
5.7 – 5.8	–	NO	–

9.2.2.2 DLL protocol selection

Table 128 holds the data-link layer protocol selections from IEC 61158-4-4 for this profile.

Table 128 – CP 4/3: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope and object	YES	–
2	Normative references	Partial	Used if needed
3	Terms and definitions	Partial	Used when applicable
4	Data Link Protocol definition	YES	a
a A device shall provide at least the necessary protocol options to fulfil the supported services.				

9.2.3   Application layer

9.2.3.1   AL service selection

Table 129 holds the Application layer service selections from IEC 61158-5-4 for this profile.

Table 129 – CP 4/3: AL service selection

Clause	Header	Presence	Constraints
Whole document	Application layer service definition – Type 4 elements	YES	–

Normal class devices shall support the Real Variable Objects needed for the variable types, which are actually present in the device, and Proxy Variable Objects for all of the variable types listed in IEC 61158-5-4, 5.2.

9.2.3.2   AL protocol selection

Table 130 holds the Application layer protocol selections from IEC 61158-6-4 for this profile.

Table 130 – CP 4/3: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Application layer protocol specification – Type 4 elements	YES	See a
a A device shall provide at least the necessary protocol options to fulfil the supported services. If the Service Write with SecureDataExchange is required in a device, the Service Method shall also be provided in order to perform the exchange of Nonce'es for creating and validating Signatures.				

9.2.4   Performance indicator selection

9.2.4.1   Performance indicator overview

Table 131 provides an overview of CP 4/3 performance indicators.

Table 131 – CP 4/3: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	Application dependent
Number of end-stations	YES	Up to 125
Basic network topology	YES	—
Number of switches between end-stations	YES	Communication between switches must be at least 100 Mbit/s
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	NO	—
Non-time-based synchronization accuracy	YES	—
Redundancy recovery time	YES	—

9.2.4.2 Performance indicator dependencies

Table 132 shows the overview of performance indicators applicable to CP 4/3.

Table 132 – CP 4/3: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Non-time-based synchronization accurancy	Redundancy recovery time
Delivery time		YES 9.2.4.2.1	YES 9.2.4.2.3	YES 9.2.4.2.1	YES 9.2.4.2.1	NO	NO	YES 9.2.4.2.2
Number of end-stations	YES 9.2.4.2.1		NO	NO	YES 9.2.4.2.1	YES 9.2.4.2.1	NO	NO
Basic network topology	YES 9.2.4.2.3	NO		NO	NO	NO	NO	NO
Number of switches between end-stations	YES 9.2.4.2.1	NO	NO		YES 9.2.4.2.1	YES 9.2.4.2.1	YES 9.2.4.2.1	YES 9.2.4.2.2
Throughput RTE	YES 9.2.4.2.1	YES 9.2.4.2.1	NO	YES 9.2.4.2.1		NO	NO	YES 9.2.4.2.2
Non-RTE bandwidth	NO	YES 9.2.4.2.1	NO	YES 9.2.4.2.1	NO		NO	NO
Non-time-based synchronization accuracy	YES 9.2.4.2.4	NO	NO	YES 9.2.4.2.4	NO	NO		NO
Redundancy recovery time	NO	NO	NO	YES 9.2.4.2.2	NO	NO	NO	

9.2.4.2.1 Calculation of Delivery time

Delivery time is calculated according to Formula (18). Derivation of this formula is given in A.3.6. Switches are numbered as #1 at senders connection up to #NoS at the receivers connection.

$$DT = STTs + STTr + NoNt\ (ttES + pd + QTES) + cd \tag{18}$$

$$\sum_{i=1}^{NoS-1} (NoNs(i)(NoS - i)(ttSS + pd + QTSS))$$

where

cd	is the cable delay time;
DT	is the delivery time;
NoNs[x]	is the number of RTE end-stations connected to switch No x. This includes number of RTE end-stations connected to the switch by other switches, which are not included in the path from sender to receiver. Switches are numbered as #1 at senders connection up to #NoS at the receivers connection;
NoNt	is the number of RTE end-stations, in total;
NoS	is the number of switches in path from sender to receiver;
pd	is the propagation delay within a Switch;
QTES	is the Ethernet enforced quiet time on end-station to switch link;
QTSS	is the Ethernet enforced quiet time on switch-to-switch link;
STTr	is the receiver stack transversal time including Phy and MAC;
STTs	is the sender stack transversal time including Phy and MAC access interval restriction;
ttES	is the P-NET transfer time RTE end-station to switch at maximum APDU size;
ttSS	is the P-NET transfer time switch-to-switch at maximum APDU size.

The delivery time is increased with a timeout value in the event of a lost frame. The timeout value is application dependent, and can be configured for each network in an application. The typical timeout value is 100 ms.

9.2.4.2.2 Redundancy recovery time

The redundancy recovery time depends on the switches that are used for the specific application. It is recommended to use switches that support the rapid spanning tree protocol (RSTP), or similar, to minimize the redundancy recovery time.

9.2.4.2.3 Basic network topology

When using WLAN, the total delay caused by wireless transmissions may change depending on the signal/noise ratio. To obtain a required delivery time in a system using WLAN, the worst case delay time for the WLAN equipment shall be included in the cable delay time, cd.

9.2.4.2.4 Non time-base synchronization accuracy

The non time-base synchronization accuracy is calculated according to Formula (19).

Non time-base synchronization accuracy = DT – DTb (19)

where

DTb	is the delivery time, calculated by best-case values;
DT	is the delivery time, calculated by worst-case values.

9.2.4.2.5   Throughput RTE

The throughput RTE is calculated according to Formulae (20) and (21).

Minimum RTE Throughput = FS x minAPDUs   (20)

Maximum RTE Throughput = FS x maxAPDUs

(21)

where

FS	is the number of frames allowed to be sent per second for one RTE end-station;
minAPDUs	is the size of the minimum APDU;
maxAPDUs	is the size of the maximum APDU.

9.2.4.2.6   Non-RTE bandwidth

The time not occupied by RTE communication can be used for non-RTE communication. Each RTE end-station has a network access restriction that limits the number of frames produced onto the RTE network.

The RTE load is determined by the critical switch-to-switch link between two devices engaged in a non-RTE communication. The critical switch-to-switch link is where the most RTE frames can occur.

The non-RTE bandwidth (%) can be calculated by using Formula (22).

Non-RTE Throughput = (1 – (NoCEN x NoAS)(ttSS+QTSS)) x 100   (22)

where

NoCEN	is the number of RTE end-stations which can produce frames on the critical switch-to-switch link;
NoAS	is the number of accesses allowed per device per second;
ttSS	is the P-NET transfer time switch-to-switch at maximum APDU size;
QTSS	is the Ethernet enforced quiet time on switch-to-switch link.

See example of non-RTE bandwidth calculation in A.3.3.

9.2.4.3   Consistent set of performance indicators

Table 133 shows a consistent set of performance indicators for a typical configuration for factory automation.

Details for calculating the performance indicators are given in Clause A.2.

Parameters used for the calculation of Table 133 are shown in Table 134. All these parameters are the result of the described scenario and the related calculations of performance indicators.

Table 133 – CP 4/3: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery time	6,3 ms	
Minimum delivery time	0,564 ms	
Throughput RTE minimum	5 Koctets/s	
Throughput RTE maximum	64 Koctets/s	
Non-RTE bandwidth	75 %	Non-RTE device to non-RTE device
Non-time-based synchronization accuracy	5,7 ms	
Redundancy recovery time	1 s	Example value. See 9.2.4.2.2
Number of RTE end-stations, in total	30	
Number of switches in path from sender to receiver	4	

Table 134 – Parameters for calculation of consistent set of PIs

Symbol	Description	Value
STTs	Sender stack transversal time including Phy and MAC access interval restriction	1 250 µs
STTR	Receiver stack transversal time including Phy and MAC	250 µs
ttESmin	P-NET transfer time at 10 Mbit/s (at min APDU size)	57 µs
ttES	P-NET transfer time at 10 Mbit/s (at maximum APDU size)	114,4 µs
ttSS	P-NET transfer time at 100 Mbit/s (at maximum APDU size)	11,44 µs
QTES	Ethernet enforced quiet time at 10 Mbit/s	9,4 µs
QTSS	Ethernet enforced quiet time at 100 Mbit/s	0,94 µs
cd	Cable delay. Sum of cable from sender to receiver is 200 m	1 µs
pd	Propagation delay within a switch. Required minimum value	7 µs
NoS	Number of switches in path from sender to receiver	4
NoNt	Number of RTE end-stations, in total	30
NoNs[1]	Number of RTE end-stations connected to switch number 1	10
NoNs[2]	Number of RTE end-stations connected to switch number 2	5
NoNs[3]	Number of RTE end-stations connected to switch number 3	5
NoNs[4]	Number of RTE end-stations connected to switch number 4	10

10 Communication Profile Family 6 (INTERBUS®[8]) – RTE communication profiles

10.1 General overview

Communication Profile Family 6 (CPF 6) defines communication profiles based on IEC 61158 series Type 8 and Type 10 specifications, which correspond to parts of the communication systems commonly known as INTERBUS and PROFINET.

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8 INTERBUS is the trade name of Phoenix Contact GmbH & Co. KG. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name INTERBUS. Use of the trade name INTERBUS requires permission of the trade name holder.

In this document, the following communication profiles are specified for CPF 6:

– Profile 6/4

  This profile defines service and protocol selections together with a mapping for a linking-device connecting Type 8 and Type 10 communication systems. It comprises CP 6/1 master and CP 3/4 device together with a mapping.

– Profile 6/5

  This profile defines service and protocol selections together with a mapping for a linking-device connecting Type 8 and Type 10 communication systems. It comprises CP 6/1 master and CP 3/5 device together with a mapping.

– Profile 6/6

  This profile defines service and protocol selections together with a mapping for a linking-device connecting Type 8 and Type 10 communication systems. It comprises CP 6/1 master and CP 3/6 device together with a mapping.

Figure 6 shows the linking-device CPs and the relation to other Type 8 and Type 10 CPs.
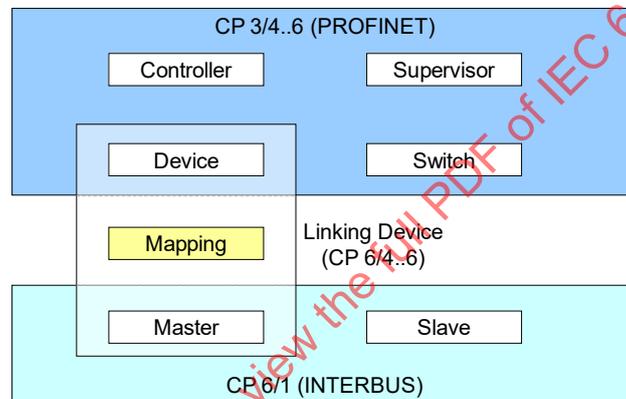
Figure 6 – Linking-device communication profiles RTE-network context

Linking-devices, which comply with a communication profile can be further classified by a CP identifier. The CP identifier assignment is shown in Table 135.

Table 135 – CPF 6: device CP identifier assignment

Profile	Linking device
Profile 6/4	649
Profle 6/5	659
Profle 6/6	669

Each communication profile provides a well-defined set of provisions. For a distinct device further selections of services, parameters and parameter values shall be made. These selections should be described according to ISO 15745-3 as INTERBUS device profiles in the form of an INTERBUS device profile exchange description. An INTERBUS device profile based on a CP shall specify the CP identifier in the following format:

  <communicationEntity ... communicationProfile="[CP identifier]" ...>

10.2 Profile 6/4

10.2.1 Mapping

Type 8 devices shall be assigned to Type 10 slots or Type 10 subslots.

NOTE 1   The mapping concept itself is not part of the communication profile. The mapping concept used could be described in the device description of the linking-device according to ISO 15745-1.

Type 10 slots or subslots could have 1 or more Type 8 devices assigned to it.

Figure 7 depicts the mapping principle. The data mapping is shown in Figure 8.
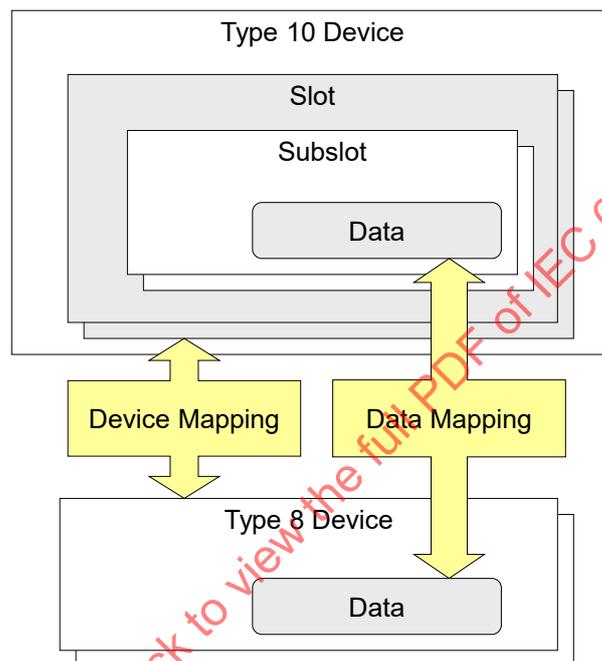
Figure 7 – Linking-device mapping principle
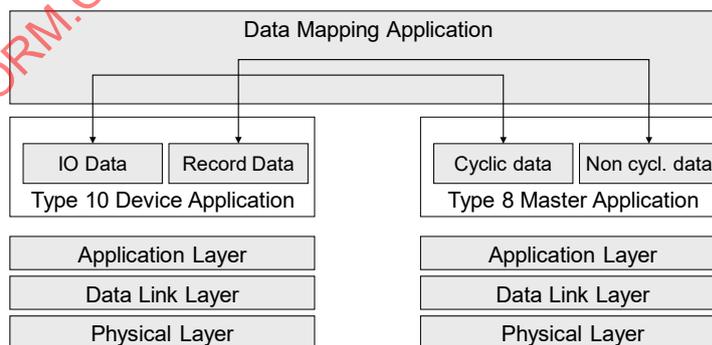
Figure 8 – Data Mapping

The specific applications realize the services of types 8 and 10 according to the defined communication profiles. The data objects of the network applications are interconnected with a mapping application which shall implement the following behavior:

- the Input/Output data of the subslot shall be mapped to the cyclic data of the corresponding Type 8 slaves;

- the process data status information (IOPS/IOCS) of the subslot shall be locally generated because there is no corresponding process data status in Type 8 Systems;

- the record data objects of the subslot shall be mapped to the non cyclic data of the corresponding Type 8 slaves.

NOTE 2   It is possible to describe the Input/Output data and the record data of a subslot in the device description of the linking-device according to ISO 15745-1.

10.2.2   Type 10 service and protocol selection

10.2.2.1   Physical layer

The Type 10 physical layer of this profile shall be according to ISO/IEC/IEEE 8802-3. Linking-devices shall use a data rate of at least 100 Mbit/s and full-duplex mode at least for one port. The auto negotiation and crossover function specified in IEEE 802-3 shall be used.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-3.

10.2.2.2   Data-link layer

The Type 10 data-link layer of a linking-device shall be according to ISO/IEC/IEEE 8802-3, IEEE 802.1AB, IEEE 802.1D, and IEEE 802.1Q.

From the various optional Management Information Bases (MIB) at least the LLDP MIB (see IEEE 802.1AB) and SNMP MIB-II (see RFC 1213) are required.

10.2.2.3   Application layer

10.2.2.4   AL service selection

The linking-device shall provide the CP 3/4 service selection as specified in 8.2.3.2.1.

10.2.2.5   AL protocol selection

The linking-device shall provide the CP 3/4 protocol selection as specified in 8.2.3.2.1.

10.2.3   Type 8 service and protocol selection

10.2.3.1   Physical layer

The linking-device shall provide the CP 6/1 master PhL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-6.

10.2.3.2   Data-link layer

The linking-device shall provide the CP 6/1 master DLL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

10.2.3.3   Application layer

The linking-device shall provide the CP 6/1 master AL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

Performance indicator selection

10.2.3.4 Performance indicator overview

Table 136 specifies the relevant performance indicators for the Type 10 network node of a linking-device.

Table 136 – Linking-device Type 10 network PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	See 10.2.3.5.2 for the delivery time of data from the Type 8 network
Number of end-stations	YES	–
Basic network topology	YES	–
Number of switches between end-stations	YES	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	–
Non-time-based synchronization accuracy	–	–
Redundancy recovery time	YES	For the Type 10 network only

10.2.3.5 Performance indicator dependencies

10.2.3.5.1 Performance indicator dependency matrix

Table 105 specifies the dependencies of the performance indicators of the Type 10 network of a linking-device.

10.2.3.5.2 Delivery time for Type 8 slave data

The performance indicator delivery time for the Type 10 network (DT10) is defined in 8.2.4.2.2.

The delivery time for data from a Type 8 slave can be calculated by Formula (23).

$$DTLD = DT10 + cta\_M + [M \times 13 \times (8 + sl8) + 3 \times a] \times T_{bit} + t_S \qquad (23)$$

where

DTLD	is the total delivery time between a Type 8 slave and a Type 10 entity;
DT10	is the delivery time of the Type 10 network;
cta_M	is the application cycle time of the mapping application in the linking-device;
M	is the Type 8 Master implementation factor;
n	is the number of data octets (user data; payload);
sl8	is the number of Type 8 slaves connected to the linking-device;
T_{bit}	is the nominal bit duration (see 27.2 in IEC 61158-2);
t_S	is the software processing time of the Type 8 master (application specific).

10.2.3.6 Consistent set of performance indicators

The consistent set of performance indicators for the Type 10 network is described in 8.2.4.3.

10.3 Profile 6/5

10.3.1 Mapping

The mapping is specified in 10.2.1.

10.3.2   Type 10 service and protocol selection

10.3.2.1   Physical layer

The Type 10 physical layer of this profile shall be according to ISO/IEC/IEEE 8802-3. Linking-devices shall use a data rate of at least 100 Mbit/s and full-duplex mode at least for one port. The auto negotiation and crossover function specified in ISO/IEC/IEEE 8802-3 shall be used.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-3.

10.3.2.2   Data-link layer

The Type 10 data-link layer of a linking-device shall be according to ISO/IEC/IEEE 8802-3, IEEE 802.1AB, IEEE 802-1D, and IEEE 802-1Q.

From the various optional Management Information Bases (MIB) at least the LLDP MIB (see IEEE 802.1AB) and SNMP MIB-II (see RFC 1213) are required.

10.3.2.3   Application layer

10.3.2.4   AL service selection

The linking-device shall provide the CP 3/5 service selection as specified in 8.3.3.1.1

10.3.2.5   AL protocol selection

The linking-device shall provide the CP 3/5 protocol selection as specified in 8.3.3.2.1.

10.3.3   Type 8 service and protocol selection

10.3.3.1   Physical layer

The linking-device shall provide the CP 6/1 master PhL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-6.

10.3.3.2   Data-link layer

The linking-device shall provide the CP 6/1 master DLL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

10.3.3.3   Application layer

The linking-device shall provide the CP 6/1 master AL service and protocol selection as specified for CP identifier 619 in IEC 61784-1, Clause 10.

10.3.4   Performance indicator selection

10.3.4.1   Performance indicator overview

See 10.2.3.4.

10.3.4.2   Performance indicator dependencies

See 10.2.3.5.

10.3.4.3 Consistent set of performance indicators

The consistent set of performance indicators for the Type 10 network is described in 8.3.4.3.

10.4 Profile 6/6

10.4.1 Mapping

The mapping is specified in 10.2.1.

10.4.2 Type 10 service and protocol selection

10.4.2.1 Physical Layer

The Type 10 physical layer of this profile shall be according to ISO/IEC/IEEE 8802-3. Linking-devices shall use a data rate of at least 100 Mbit/s and full-duplex mode at least for one port. The auto negotiation and crossover function specified in ISO/IEC/IEEE 8802-3 shall be used.

Recommended connectors, cables and installation guidelines are specified in IEC 61784-5-3.

10.4.2.2 Data-link layer

The Type 10 DLL of a linking-device shall be according to ISO/IEC/IEEE 8802-3, IEEE 802.1AB, IEEE 802.1D, and IEEE 802.1Q.

From the various optional Management Information Bases (MIB) at least the LLDP MIB (see IEEE 802.1AB) and SNMP MIB-II (see RFC 1213) are required.

10.4.2.3 Application layer

10.4.2.4 AL service selection

The linking-device shall provide the CP 3/6 service selection as specified in 8.3.3.1.1.

10.4.2.5 AL protocol selection

The linking-device shall provide the CP 3/6 service selection as specified in 8.3.3.2.1.

10.4.3 Type 8 service and protocol selection

The Type 8 service and protocol selection is specified in 10.3.3.

10.4.4 Performance indicator selection

10.4.4.1 Performance indicator overview

See 10.2.3.4.

10.4.4.2 Performance indicator dependencies

See 10.2.3.5.

10.4.4.3 Consistent set of performance indicators

The consistent sets of performance indicators for the Type 10 network is described in 8.4.4.3.

11 Communication Profile Family 10 (Vnet/IP[9]) – RTE communication profiles

11.1 General overview

Communication Profile Family 10 (CPF 10) defines communication profiles using the principles, methodology and model of ISO/IEC 7498-1. In addition, it also follows the three-layer basic fieldbus reference model described in IEC 61158-1.

The OSI model provides a layered approach to communication standards, whereby the layers can be developed and modified independently. CPF 10 is based on the three-layer structure, and each layer of OSI seven layers is mapped onto these three layers as follows.

Functions of the intermediate OSI layers, layers 5, 6 and 7, are consolidated into the Application layer.

Functions of the intermediate OSI layers, layers 2, 3 and 4, are consolidated into the data-link layer.

Likewise, some features common to users of the Fieldbus Application layer are provided to simplify user operation.

Table 137 shows the OSI layers, their functions and the equivalent layers in the CPF10 layer model.

Table 137 – OSI layers and CPF 10 layers

OSI layer	Function	CPF 10 layer
7 Application	Translates demands placed on the communication stack into a form understood by the lower layers and vice versa	Application
6 Presentation	Converts data to/from standardized network formats	
5 Session	Synchronizes and manages data	
4 Transport	Provides transparent reliable data transfer	Data-link
3 Network	Performs message routing	
2 Data-link	Controls access to the communication medium. Performs error detection	
1 Physical	Encodes/decodes signals for transmission/reception in a form appropriate to the communication medium. Specifies communication media characteristics	Physical

Table 138 shows an overview of the communication profile for CPF 10.

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[9] Vnet/IP is a trade name of Yokogawa Electric Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

Table 138 – Overview of CPF 10 profile

Layer	Protocol
Application	IEC 61158-6-17
Transport	RFC 768 and IEC 61158-4-17
Network	RFC 791
Data-link	ISO/IEC 8802-2 and ISO/IEC/IEEE 8802-3
Physical	ISO/IEC/IEEE 8802-3

11.2 Profile 10/1

11.2.1 Physical layer

ISO/IEC/IEEE 8802-3 shall be used.

11.2.2 Data link layer

11.2.2.1 MAC sublayer

ISO/IEC/IEEE 8802-3 shall be used.

11.2.2.2 LLC sublayer

ISO/IEC/IEEE 8802-3 shall be used.

11.2.2.3 Network sublayer

11.2.2.3.1 General

Internet standard RFC 791 and its amendments and successors shall be used.

Internet standard RFC 2236 shall be used to perform multicasting.

11.2.2.3.2 Unicast address

IPv4 class C private address scope shall be used. Each subnetwork of a domain has the respective IP network address as follows.

IP address for the interface connected to the primary network:

– 192.168.(Domain number).(Host address)

IP address for the interface connected to the secondary network:

– 192.168.128+(Domain number).(Host address)

Each node of a redundant station has a respective IP host address as follows.

– Host address: (Station number) X 2 or (Station number) X 2 + 1

11.2.2.3.3 Group address

IPv4 class D Organization-Local Scope shall be used as group addresses for multicasting. Both the primary network and the secondary network require two group addresses: one for multicasting to all stations in the domain, and another for multicasting to all stations in the multi-domain network.

To assign these group addresses to the stations, AD-HOC Block group address 224.0.23.33 may be used.

NOTE   This group address is registered with the Internet Assigned Numbers Authority (IANA).

11.2.2.3.4   TOS

The following four TOS parameter values shall be used for the data-link service:

– time synchronization;

– high priority;

– low priority;

– general purpose.

11.2.2.4   Transport sublayer

11.2.2.4.1   Transport service selection

Internet standard RFC 768 (UDP) and its amendments and successors, and the data-link layer specified in IEC 61158-3-17 and IEC 61158-4-17 shall be used.

UDP port number 5313 shall be used.

NOTE   This UDP port number is registered with the Internet Assigned Numbers Authority (IANA).

Table 139 specifies the DLL service selection within IEC 61158-3-17.

Table 139 – CP 10/1: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative reference	YES	–
3	Definitions	YES	–
4	Overview of the data-link layer service	YES	–
5	DLSAP management service	YES	–
6	Connectionless-mode Data Link Service	YES	–
7	DL-management Service	YES	–

11.2.2.4.2   Transport protocol selection

Table 140 specifies the DLL protocol selection within IEC 61158-4-17.

Table 140 – CP 10/1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative reference	YES	–
3	Definitions	YES	–
4	Overview of the DL-protocol	YES	–
5	DLPDU-parameter structure and encoding	YES	–
6	Local parameters and resources	YES	–
7	DL-service elements of procedure	YES	–
8	DL-support protocol	YES	–

11.2.2.4.3   Parameter selection

Table 141 shows the parameter selection.

Table 141 – Transport Layer Parameter selection

Parameter Symbol	Parameter name	Usage	Value
$P(ND)$	max-domains	M	31
$P(HC)$	max-hop-count	M	7
$P(NS)$	max-stations	M	64
$P(GA_{1A})$	IP-group-address-1A	M	239.192.24.0
$P(GA_{1B})$	IP-group-address-1B	M	239.192.24.1
$P(GA_{2A})$	IP-group-address-2A	M	239.192.24.4
$P(GA_{2B})$	IP-group-address-2B	M	239.192.24.5
$P(AB_{DA})$	IP-base-address-domain-A	M	192.168.0.0
$P(AB_{DB})$	IP-base-address-domain-B	M	192.268.128.0
$P(MRC_{AUS})$	max-retry-count-AUS	M	5
$P(MRC_{ASS})$	max-retry-count-ASS	M	5
$P(MOS)$	max-outstanding-number	M	10
$P(TNR_{AUS})$	max-response-time-AUS	M	50 ms
$P(TNR_{ASS})$	max-response-time-ASS	M	500 ms
$P(TWT_{AUS})$	wait-time-AUS	M	100 ms
$P(TWT_{ASS})$	wait-time-ASS	M	100 ms
$P(TID_{ASS})$	inter-DTPDU-time	M	500 ms
$P(MC)$	macro-cycle-period	M	100 ms
$P(SD_{UUS})$	starting-delay-UUS	M	{1,11,21,31,41,56,66,76,86} ms
$P(SD_{AUS})$	starting-delay-AUS	M	{1,11,21,31,41,56,66,76,86} ms
$P(SD_{ASS})$	starting-delay-ASS	M	{6,16,26,36,51,61,71,81,91} ms
$P(SD_{MUS})$	starting-delay-MUS	M	{8,28,48,68,88} ms
$P(SD_{MSS})$	starting-delay-MSS	M	{46} ms
$P(TD_{UUS})$	time-duration-UUS	M	1 ms
$P(TD_{AUS})$	time-duration-AUS	M	1 ms
$P(TD_{ASS})$	time-duration-ASS	M	1 ms
$P(TD_{MUS})$	time-duration-MUS	M	1 ms

Parameter Symbol	Parameter name	Usage	Value
P(TD$_{MSS}$)	time-duration-MSS	M	1 ms
P(TO$_{UUS}$)	offset-time-UUS	M	1 ms
P(TO$_{AUS}$)	offset-time-AUS	M	1 ms
P(TO$_{ASS}$)	offset-time-ASS	M	1 ms
P(TO$_{MUS}$)	offset-time-MUS	M	1 ms
P(TO$_{MSS}$)	offset-time-MSS	M	1 ms
P(DV$_{UUS}$)	divisor-for-grouping-UUS	M	5
P(DV$_{AUS}$)	divisor-for-grouping-AUS	M	5
P(DV$_{ASS}$)	divisor-for-grouping-ASS	M	5
P(DV$_{MUS}$)	divisor-for-grouping-MUS	M	5
P(DV$_{MSS}$)	divisor-for-grouping-MSS	M	5
P(KS)	key size	M	4 octet
P(AS)	authentication field size	M	2 octet
P(PN)	prime-number	M	0b01011001
P(BS)	base-number	M	251
P(UD)	key-update-time	M	3 600 s

11.2.3   Application layer

11.2.3.1   General

The application layer specified in IEC 61158-5-17 and IEC 61158-6-17 shall be used.

11.2.3.2   AL service selection

Table 142 specifies the AL service selection within IEC 61158-5-17.

Table 142 – CP 10/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	–
3	Definitions	YES	–
4	Concepts	YES	–
5	ASEs	YES	–
6	ARs	YES	–
7	Summary of FAL classes	YES	–
8	Permitted FAL services by AREP role	YES	–

11.2.3.3   AL protocol selection

Table 143 specifies the AL protocol selection within IEC 61158-6-17.

Table 143 – CP 10/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative reference	YES	–
3	Definitions	YES	–
4	Abstract syntax description	YES	–
5	Transfer syntax	YES	–
6	FAL protocol state machines structure	YES	–
7	AP-Context state machine	YES	–
8	FAL Service Protocol Machines (FSPMs)	YES	–
9	Application Relationship Protocol Machines (ARPMs)	YES	–
10	DLL Mapping Protocol Machine (DMPM)	YES	–

11.2.4 Performance indicator selection

11.2.4.1 Performance indicator overview

Table 144 shows the overview of performance indicators applicable to CP 10/1.

Table 144 – CP 10/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	None
Number of end-stations	YES	None
Basic network topology	YES	None
Number of switches between end-stations	YES	None
Throughput RTE	YES	None
Non-RTE bandwidth	YES	None
Time synchronization accuracy	YES	None
Non-time-based synchronization accuracy	NO	–
Redundancy recovery time	YES	None

11.2.4.2 Performance indicator dependencies

11.2.4.2.1 General

Table 145 shows the dependencies between performance indicators for CP 10/1.

Table 145 – CP 10/1: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy	Redundancy recovery time
Delivery time		NO	YES 11.2.4.2.2	YES 11.2.4.2.2	NO	NO	NO	NO
Number of end-stations	NO		YES 11.2.4.2.3	YES 11.2.4.2.3	NO	NO	NO	NO
Basic network topology	YES 11.2.4.2.2	YES 11.2.4.2.3		YES 11.2.4.2.3	NO	NO	NO	NO
Number of switches between end-stations	NO	NO	YES 11.2.4.2.3		NO	NO	NO	NO
Throughput RTE	NO	NO	YES 11.2.4.2.4	NO		NO	NO	NO
Non-RTE bandwidth	NO	NO	YES 11.2.4.2.5	NO	NO		NO	NO
Time synchronization accuracy	NO	NO	YES 11.2.4.2.6	NO	NO	NO		NO
Redundancy recovery time	NO	NO	YES 11.2.4.2.7	NO	NO	NO	NO	

11.2.4.2.2 Calculation of delivery time

The actual delivery time can be calculated by Formula (24).

$$DT = STTs + STTr + Trate \times Dlen + Cdly \times Clen + Spd \times NoS \tag{24}$$

wherxe

DT is the delivery time;

$STTs$ is the sender stack traversal time including PhL, DLL and AP;

$STTr$ is the receiver stack traversal time including PhL, DLL and AP;

$Trate$ is the transfer bit rate;

$Dlen$ is the bit length of the complete Ethernet frame;

$Cdly$ is the cable delay;

$Clen$ is the cable length;

Spd is the switch delay under not congested condition;

NoS is the number of switches.

The maximum delivery time for communication between two end-stations belonging to the same domain can be calculated by Formula (25).

$$DTmax1 = 20 \ ms + \ Cdly \times Clen + Spd \times NoS \qquad (25)$$

where

DTmax1	is the maximum delivery time for communication between two end-stations belonging to the same domain;
Cdly	is the cable delay;
Clen	is the cable length;
Spd	is the switch delay under not congested condition;
NoS	is the number of switches.

The maximum delivery time for communication between two end-stations belonging to different domains can be calculated by Formula (26).

$$DTmax2 = 50 \ ms + Cdly \times Clen + Spd \times NoS \qquad (26)$$

where

DTmax2	is the maximum delivery time for communication between two end-stations belonging to different domains;
Cdly	is the cable delay;
Clen	is the cable length;
Spd	is the switch delay under not congested condition;
NoS	is the number of switches.

The maximum delivery time with one lost frame for communication between two end-stations belonging to the same domain can be calculated by Formula (27).

$$DTlost1 = 10 \ ms + DTmax1 \qquad (27)$$

where

DTlost1	is the maximum delivery time with one lost frame for communication between two end-stations belonging to the same domain;
DTmax1	is the maximum delivery time for communication between two end-stations belonging to the same domain.

The maximum delivery time with one lost frame for communication between two end-stations belonging to different domains can be calculated by Formula (28).

$$DTlost2 = 150 \ ms + DTmax2 \qquad (28)$$

where

DTlost2	is the maximum delivery time with one lost frame for communication between two end-stations belonging to different domains;
DTmax2	is the maximum delivery time for communication between two end-stations belonging to different domains.

11.2.4.2.3   Network structure restriction

If the network consists of only one domain, the number of the RTE end-stations is restricted to 64.

If the network consists of more than two domains, the number of RTE end-stations in the domain is restricted to 64. The maximum number of the domain shall be 64.

The topology of interconnection among domains shall be a tree topology.

The topology of interconnection among bridges in a domain shall be a tree topology or a ring topology.

The number of switches between any two end-stations in a same domain shall be less than 7, and the number of routers (layer-3-switches) between any two domains shall be less than 4.

11.2.4.2.4   Throughput RTE restriction

The throughput RTE which is generated by communication among end-stations which belong to the same domain shall be limited to less than 10 Moctets per second.

The throughput RTE which is generated by communication going out from any domain shall be limited to less than 10 Moctets per second. And the throughput RTE which is generated by communication coming into any domain shall be limited to less than 10 Moctets per second.

11.2.4.2.5   Non-RTE bandwidth restriction

The non-RTE bandwidth shall be less than 500 Mbit/s. If the network consists of more than two domains, routers shall control the non-RTE traffic in order to make the non-RTE bandwidth of any domain less than 500 Mbit/s, otherwise total non-RTE bandwidth generated in the network shall be less than 500 Mbit/s.

11.2.4.2.6   Time synchronization accuracy

The time synchronization accuracy between any two end nods which belong to the same domain is ±1 ms or less, and the time synchronization accuracy between any two end nods in the different domain is ± 5 ms or less.

11.2.4.2.7   Redundancy recovery time

The redundancy recovery time for communication between any two end-stations which belong to the same domain is less than 200 ms, and the redundancy recovery time for communication between any two end-stations which belong to the different domains is less than 600 ms.

11.2.4.3   Consistent set of performance indicators

Table 146 shows a consistent set of performance indicators which is applicable to communication between two end-stations belonging to the same domain.

Table 146 – CP 10/1: Consistent set of PIs for the communication between two end-stations belonging to the same domain

Performance indicator	Value	Constraints
Delivery time	20 ms	Excluding cable_delay and nominal switch_delay
Number of end-stations	64	None
Number of switches between end-stations	7	None
Throughput RTE	10 M octet/s	None
Non-RTE bandwidth	0 % – 50 % (500 Mbit/s)	None
Time synchronization accuracy	< 1 ms	None
Non-time-based synchronization accuracy	Not applicable	–
Redundancy recovery time	< 200 ms	None

Table 147 shows a consistent set of performance indicators which is applicable to communication between two end-stations belonging to different domains.

**Table 147 – CP 10/1: Consistent set of PIs for the communication
between two end-stations belonging to different domains**

Performance indicator	Value	Constraints
Delivery time	50 ms	Excluding cable_delay and nominal switch_delay
Number of end-stations	4 096	–
Number of switches between end-stations	39	Including 4 layer-3-switches
Throughput RTE	10 M octet/s	–
Non-RTE bandwidth	0 % – 50 % (500 Mbit/s)	–
Time synchronization accuracy	< 5 ms	–
Non-time-based synchronization accuracy	Not applicable	–
Redundancy recovery time	< 600 ms	–

Table 148 shows a consistent set of performance indicators which is applicable to communication between two end-stations belonging to the same domain with one lost flame.

**Table 148 – CP 10/1: Consistent set of PIs for the communication between
two end-stations belonging to the same domain with one lost flame**

Performance indicator	Value	Constraints
Delivery time	60 ms	Excluding cable_delay and nominal switch_delay
Number of end-stations	64	–
Number of switches between end-stations	7	–
Throughput RTE	10 M octet/s	–
Non-RTE bandwidth	0 % – 50 % (500 Mbit/s)	–
Time synchronization accuracy	< 1 ms	–
Non-time-based synchronization accuracy	Not applicable	–
Redundancy recovery time	< 200 ms	–

Table 149 shows a consistent set of performance indicators which is applicable to communication between two end-stations belonging to different domains with one lost flame.

**Table 149 – CP 10/1: Consistent set of PIs for the communication between two
end-stations belonging to different domains with one lost frame**

Performance indicator	Value	Constraints
Delivery time	200 ms	Excluding cable_delay and nominal switch_delay
Number of end-stations	4 096	–
Number of switches between end-stations	39	Including 4 layer-3-switches
Throughput RTE	10 Moctet/s	–
Non-RTE bandwidth	0 % – 50 % (500 Mbit/s)	–
Time synchronization accuracy	< 5 ms	–
Non-time-based synchronization accuracy	Not applicable	–
Redundancy recovery time	< 600 ms	–

12 Communication Profile Family 11 (TCnet[10]) – RTE communication profiles

12.1 General overview

Communication Profile Family 11 defines three types of communication profile based on IEC 61158-3-11, IEC 61158-4-11, IEC 61158-5-11 and IEC 61158-6-11 which corresponds to the communication systems commonly known as TCnet.

– Profile 11/1 (TCnet-star)

   This profile constitutes a TCnet communication system with star topology. It contains a selection of AL, and DLL services and protocol definitions from IEC 61158-3-11, IEC 61158-4-11, IEC 61158-5-11 and IEC 61158-6-11.

– Profile 11/2 (TCnet-loop 100 with physical layer of 100 Mbit/s)

   This profile constitutes a TCnet communication system with loop (ring) topology. It contains a selection of AL, and DLL services and protocol definitions from IEC 61158-3-11, IEC 61158-4-11, IEC 61158-5-11 and IEC 61158-6-11.

– Profile 11/3 (TCnet-loop 1G with physical layer of 1 000 Mbit/s)

   This profile constitutes a TCnet communication system with loop (ring) topology. It contains a selection of AL, and DLL services and protocol definitions from IEC 61158-3-11, IEC 61158-4-11, IEC 61158-5-11 and IEC 61158-6-11.

Table 150 shows the overview of TCnet profile set.

Table 150 – CPF 11: Overview of profile sets

Layer	Profile 11/1, profile 11/2, profile 11/3
Application	IEC 61158-5-11, IEC 61158-6-1
Data-link	IEC 61158-3-11, IEC 61158-4-11
Physical	ISO/IEC/IEEE 8802-3

12.2 Profile 11/1

12.2.1 Physical layer

The physical layer of 100 Mbit/s shall be according to ISO/IEC/IEEE 8802-3.

Connectors and cables are specified in IEC 61784-5-11 and IEC 61918.

12.2.2 Data-link layer

12.2.2.1 DLL services selection

Table 151 specifies the DLL service selection within IEC 61158-3-11.

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10 In Japan, TCnet is a trade name of TOSHIBA Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

Table 151 – CP 11/1: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms, definitions, symbols, abbreviations and conventions	Partial	–
4	Data Link services and concept	YES	–
4.1	Overview	YES	–
4.2	General description of services	YES	–
4.3	TCC data service	YES	–
4.4	Detail description of sporadic message data service	YES	–
5	DL-management services	YES	–
5.1	General	YES	–
5.2	Facilities of the DL-Management service	YES	–
5.3	Service of the DL-management	YES	–
5.4	Overview of interactions	YES	–
5.5	Detail specification of service and interactions	YES	–

12.2.2.2   DLL protocol selection

Table 152 specifies the DLL protocol selection within IEC 61158-4-11.

Table 152 – CP 11/1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms, definitions, symbols and abbreviations	Partial	–
4	Overview of the DL-protocol	–	–
4.1	General	YES	–
4.2	Overview of the medium access control	YES	–
4.3	Service assumed from the PhL	YES	–
4.4	DLL architecture	–	–
4.4.1	Overview	YES	–
4.4.2	Star-architecture	YES	–
4.4.3	Loop-architecture	NO	–
4.5	Access control machine and schedule support functions	YES	–
4.6	Local parameters, variables, counters, timers and queues	–	–
4.6.1	Overview	YES	–
4.6.1.1	General		
4.6.1.2	Summary of variables, parameters, counters, timers for star-architecture	YES	–
4.6.1.3	Summary of variables, parameters, counters, timers for loop-architecture	NO	–
4.6.2	Type 11 common variables, parameters, counters, timers and queues	YES	Relevant values and features to star-architecture
4.6.3	Star-architecture specific variables, parameters counters timers and queues	YES	–
4.6.4	Loop-architecture specific variables, parameters, counters timers and queues	NO	–
5	General structure and encoding of PhIDEs and DLPDU and related elements of procedure	YES	See Table 153
6	DLPDU-specific structure, encoding and elements of procedure	YES	See Table 154
7	DLE elements of procedure	–	–
7.1	DLE elements of procedure for star-architecture	YES	–
7.2	DLE elements of procedure for loop-architecture	NO	–
7.3	Serializer and deserializer	YES	–
7.4	DLL management protocol	–	–
7.4.1	DLL management protocol for star-architecture	YES	–
7.4.2	DLL management protocol for loop-architecture	NO	–

Table 153 – CP 11/1: DLL protocol selection of Clause 5

Clause	Header	Presence	Constraints
5.1	Overview	YES	–
5.2	PhIDU structure and encoding	YES	–
5.3	Common MAC frame structure, encoding and elements of procedure	YES	–
5.4	Elements of the MAC frame	–	–
5.4.1	General	YES	–
5.4.2	Preamble field	YES	–
5.4.3	Start frame delimiter (SFD)	YES	–
5.4.4	Address field	YES	–
5.4.5	Length/type field	YES	–
5.4.6	Frame control field (FC)	–	–
5.4.6.1	Structure of FC field	YES	–
5.4.6.2	Frame type (F-type) field	YES	–
5.4.6.3	Priority field (Pri)	YES	Relevant features to star-architecture
5.4.7	Source node number field (SN)	YES	–
5.4.8	Data and pad field	YES	–
5.4.9	Frame check sequence (FCS)	YES	–
5.5	Order of bit transmission	YES	–
5.6	Invalid DLPDU	YES	–

Table 154 – CP 11/1: DLL protocol selection of Clause 6

Clause	Header	Presence	Constraints
6.1	General	YES	–
6.2	Synchronization DLPDU (SYN)	–	–
6.2.1	General	YES	–
6.2.2	Structure of SYN DLPDU	YES	–
6.2.3	Parameters of SYN DLPDU	–	–
6.2.3.1	Transmission permits node number (PN)	YES	Relevant features to star-architecture
6.2.3.2	Control word (CW)	–	–
6.2.3.2.1	CW for star-architecture	YES	–
6.2.3.2.2	CW for loop-architecture	NO	–
6.2.3.3	Slot time (ST)	YES	Relevant features to star-architecture
6.2.3.4	High-speed transmission period (Th)	YES	–
6.2.3.5	Medium-speed transmission period (Tm)	YES	–
6.2.3.6	Sporadic message transmission target-token-rotation-time period (Ts)	YES	Relevant features to star-architecture
6.2.3.7	Low-speed transmission period (Tl)	YES	–
6.2.3.8	Live list (LL)	YES	–
6.2.4	User data	YES	–
6.2.5	Sending SYN DLPDU	YES	–
6.2.6	Receiving SYN DLPDU	YES	–
6.3	Transmission complete DLPDU (CMP)	YES	–
6.4	In-ring request DLPDU (REQ)	–	–

Clause	Header	Presence	Constraints
6.4.1	General	YES	–
6.4.2	Structure of REQ DLPDU	YES	–
6.4.3	Node-mode – ESYN parameter	NO	–
6.4.4	Recipient node number (RN) Parameter	NO	–
6.4.5	User data of REQ DLPDU	YES	–
6.4.6	Sending REQ DLPDU	YES	–
6.4.7	Receiving REQ DLPDU	YES	–
6.5	Claim DLPDU (CLM)	–	–
6.5.1	General	YES	–
6.5.2	Structure of CLM DLPDU	YES	–
6.5.3	Parameter of CLM DLPDU	–	–
6.5.3.1	Residual counts of CLM DLPDU parameter (RC)	YES	–
6.5.3.2	Slot time (ST) parameter	YES	Relevant feature to star-architecture
6.5.3.3	Node mode (NM) parameter	NO	–
6.5.4	User data of CLM DLPDU	YES	–
6.5.5	Sending and receiving CLM DLPDU	YES	–
6.6	Command DLPDU (COM)	YES	–
6.6.1	General	YES	–
6.6.2	Structure of COM DLPDU	YES	–
6.6.3	Parameter of COM DLPDU	YES	–
6.6.4	User data of COM DLPDU	YES	–
6.6.5	Sending and receiving COM DLPDU	YES	Relevant feature to star-architecture
6.7	Cyclic data and cyclic data with transmission complete DLPDU (DT) and (DT-CMP)	–	–
6.7.1	General	YES	–
6.7.2	Structure of the DT DLPDU	YES	–
6.7.3	Parameters of DT DLPDU	–	–
6.7.3.1	DLCEP-address parameter	YES	–
6.7.3.2	Word length parameter (WD)	–	–
6.7.3.2.1	WD for star-architecture	YES	–
6.7.3.2.2	WD for loop-architecture	NO	–
6.7.4	Sending DT or DT-CMP DLPDU	YES	–
6.7.5	Receiving DT or DT-CMP DLPDU	YES	–
6.8	RAS DLPDU (RAS)	–	–
6.8.1	General	YES	–
6.8.2	Structure of RAS DLPDU	YES	–
6.8.3	DCEP-address parameters	YES	–
6.8.4	User data	YES	–
6.8.5	Sending and receiving RAS DLPDU	YES	Relevant feature to star-architecture
6.9	Loop repeat request DLPDU (LRR)	NO	–
6.10	Loop diagnosis DLPDU (LPD)	NO	–

12.2.3　Application layer

12.2.3.1　AL service selection

Table 155 specifies the AL service selection within IEC 61158-5-11.

In addition AL services are mapped onto the TCP/UDP/IP protocol suite, as defined in RFC 793, RFC 768 and RFC 791 respectively.

Table 155 – CP 11/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms and definitions, abbreviations and conventions	Partial	Used when applicable
4	Concepts	YES	–
5	Data type ASE	Partial	Used when applicable
6	Communication model specification	YES	–

12.2.3.2   AL protocol selection

Table 156 specifies the AL protocol selection within IEC 61158-6-11.

Table 156 – CP 11/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	Partial	Relevant reference only
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	FAL Syntax description	YES	–
5	Transfer syntax	YES	–
6	FAL protocol state machine structures	YES	–
7	FAL Service Protocol Machine (FSPM)	YES	–
8	Application Relationship Protocol Machines (ARPM)	YES	–
9	DLL Mapping Protocol Machines (DMPM)	YES	–

12.2.4   Performance indicator selection

12.2.4.1   Performance indicator overview

Table 157 shows the performance indicators overview of CP 11/1.

Table 157 – CP 11/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end-stations	YES	–
Basic network topology	YES	Star topology
Number of switches between end-stations	NO	Hubs fit, and switches should not be applicable for highest performance
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	IEC 61588 shall be installed
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	Null time switching without interruption

12.2.4.2   Performance indicator dependencies

12.2.4.2.1   Dependency matrix

Table 158 shows the dependencies between performance indicators for CP 11/1.

Table 158 – CP 11/1: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy	Non time- based synchronization accuracy	Redundancy recovery time
Delivery time		NO 12.2.4.2.2 12.2.4.2.4	NO 12.2.4.2.5	NO 12.2.4.2.2 12.2.4.2.3	NO 12.2.4.2.2 12.2.4.2.3	NO	NO	NO 12.2.4.2.6
Number of end-stations	NO		NO	YES 12.2.4.2.2 12.2.4.2.3	YES 12.2.4.2.2 12.2.4.2.3	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO	NO
Throughput RTE	YES 12.2.4.2.2 12.2.4.2.3	YES 12.2.4.2.2 12.2.4.2.3	NO		YES 12.2.4.2.2 12.2.4.2.3	NO	NO	NO
Non-RTE bandwidth	YES 12.2.4.2.2 12.2.4.2.3	YES 12.2.4.2.2 12.2.4.2.3	NO	YES 12.2.4.2.2 12.2.4.2.3		NO	NO	NO
Time synchronization accuracy	NO	NO	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	NO	NO	NO	NO	NO		NO
Redundancy recovery time	NO	NO	NO	NO	NO	NO	NO	

12.2.4.2.2　Calculation of Delivery time

Delivery time is definitely specified by the application users using the TCC data service, and the delivery time specified meets both cases of no transmission error and one lost frame with recovery.

The TCC data service provides 3 kinds of the data transmission service at the same time, that are according to the data preference and the delivery time of an APDU to be transferred using the data transmission service.

Table 159 specifies the TCC data service selection supported by this profile.

Table 159 – CP 11/1: TCC data service selection

Service ref.	Service name	Applicable	Constraint
IEC 61158-3-11 Clause 4	High-speed cyclic data transmission	YES	The range of the high-speed transmission period (T_h) is 1 ms to 160 ms, of which unit is in 0,1 ms
IEC 61158-3-11 Clause 4	Medium-speed cyclic data transmission	YES	The range of the medium-speed transmission period (T_m) is 10 ms to 1 000 ms, of which unit is in 1 ms and in multiples of the T_h
IEC 61158-3-11 Clause 4	Low-speed cyclic data transmission	YES	The range of low-speed transmission period (T_l) is 100 ms to 10 000 ms, of which unit is in 1 ms and in multiples of the T_h

The performance indicator delivery time is related to the amount of both RTE data and non-RTE data which are exchanged between the end-stations, the number of the Ethernet frame that is used for the deterministic transmission scheduling, the signal propagation delay to the end-station, the number of the end-stations and the number of the Hubs between the end-stations.

The performance indicator delivery time can be calculated using the Formulae (29), (30), (31), (32) and (33).

$$DT_H = T_h \tag{29}$$

$$DT_M = T_m \tag{30}$$

$$DT_L = T_l \tag{31}$$

$$T_h = T_{RTE} + T_{NRT} + T_{SCH} + T_{PD} + T_{MAC} \tag{32}$$

$$T_{RTE} = T_{HS} + \frac{T_{MS}}{T_m} \times T_h + \frac{T_{LS}}{T_l} \times T_h \tag{33}$$

where

DT_H	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_M	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_L	is the delivery time for the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
T_h	is the high-speed transmission time period, and is the basic cycle_time (ct) for the TCC data service;
T_m	is the medium-speed transmission time period;
T_l	is the low-speed transmission time period;
T_{RTE}	is the total sum of the frame transmit time, in which the frame of the Ethernet with the RTE data as a payload of a fixed length is sent out of the end-station within the time period of T_h. The total volume of the RTE data and the bandwidth for the non-RTE data is specified by the application user;
T_{NRT}	is the total sum of the frame transmit time, in which the frame with the non-RTE data as a payload is sent out of the end-station within the time period of T_h and is used for the standard Ethernet application on sporadic basis;
T_{SCH}	is the total sum of the frame transmit time, in which the frame is exchanged for the deterministic transmission scheduling between the end-stations. The T_{SCH} includes both the time for the synchronization DLPDU and the multiple Transmission complete DLPDUs which are specified in the IEC 61158-4-11, Clause 6;
T_{PD}	is the sum total of the signal propagation delay (pd) between the end-stations. The T_{PD} depends on the number of Hubs between the end-stations, the cable propagation delay (cd) and the number of the end-stations;
T_{MAC}	is the time for the maintenance and control, in which a new end-station is solicited to join and the periodic time operation is controlled;
T_{HS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data;
T_{MS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data;
T_{LS}	is the total sum of the frame transmit time, in which the TCC data frame conveys the low-speed cyclic data.

12.2.4.2.3 Relation between throughput RTE and non-RTE bandwidth

Figure 9 shows an example of the relation between the throughput RTE and the non-RTE bandwidth in the case of 100 Mbit/s physical layer. This profile supports the specification of a percentage of the bandwidth and/or the throughput which are used for the non-RTE and the RTE communications.
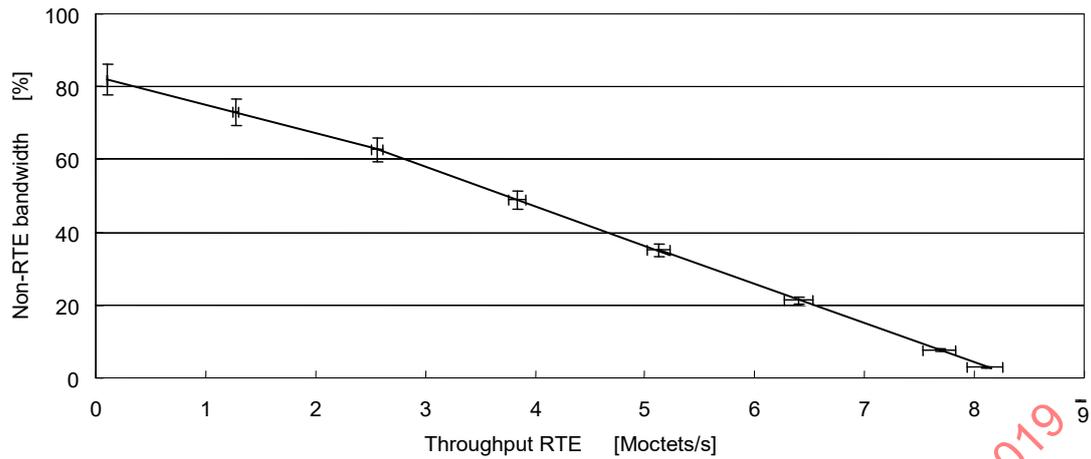
Figure 9 – CP 11/1: Throughput RTE and non-RTE bandwidth

The throughput RTE indicates the total amount of the APDU data by octet length per second, and the APDU data is sent out by the node using the TCC data service specified in the IEC 61158-3-11, 4.3. The non-RTE bandwidth indicates the total percentage of the bandwidth, which is used for the non-RTE communications by the nodes using the sporadic message data service specified in the IEC 61158-3-11, 4.4.

The total bandwidth can be calculated using the Formulae (34), (35), (36), (37), (38) and (39).

$$BW = BW_{RTE} + BW_{NRT} + BW_{CNT} \tag{34}$$

$$BW_{RTE} = TR_{RTE} \times \frac{8}{100} \tag{35}$$

$$TR_{RTE} = TR_{HS} + TR_{MS} + TR_{LS} \tag{36}$$

$$TR_{HS} = \frac{DV_{HS}}{DT_H} \tag{37}$$

$$TR_{MS} = \frac{DV_{MS}}{DT_M} \tag{38}$$

$$TR_{LS} = \frac{DV_{LS}}{DT_L} \tag{39}$$

where

BW	is the total bandwidth in %, and the 100 % is 100 Mbit/s;
BW_{RTE}	is the bandwidth used for the RTE communications in %;
BW_{NRT}	is the bandwidth used for the non-RTE communications in %;
BW_{CNT}	is the bandwidth used for the scheduling communications and for the protocol overhead in %;
TR_{RTE}	is the throughput RTE in Moctets/s;
TR_{HS}	is the throughput RTE for the high-speed cyclic data in Moctets/s;
TR_{MS}	is the throughput RTE for the medium-speed cyclic data in Moctets/s;
TR_{LS}	is the throughput RTE for the low-speed cyclic data in Moctets/s;
DV_{HS}	is the total volume of the high-speed cyclic data sent by all end-stations;
DV_{MS}	is the total volume of the medium-speed cyclic data sent by all end-stations;
DV_{LS}	is the total volume of the low-speed cyclic data sent by all end-stations;
DT_{H}	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_{M}	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_{L}	is the delivery time for the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC.

The throughput RTE or the non-RTE bandwidth depends on the BW_{CNT} for scheduling the communications and for the protocol overhead. The scheduling communications and the protocol overhead, based on the formulas provided in 12.2.4.2.2, depend on the number of the hubs between the end-stations, the cable propagation delay and the total number of the end-stations, and is related to the time for the maintenance and control in order to solicit a new end-stations and to keep the periodic time operation.

12.2.4.2.4 Number of end-stations

The maximum number of the end-stations shall be up to 254.

12.2.4.2.5 Basic network topology

The network topology supported by this profile is of a hierarchical star. The number of layers in a hierarchy is an application specific and is determined on the basis of the number of end-stations, their physical location, and the distance between the end-stations. The maximum number of hubs between any 2 end-stations shall be up to 7.

12.2.4.2.6 Redundancy recovery time

The maximum time from a failure to become fully operational again in case of a single permanent failure is almost 0 time period. This profile supports fully operational without the interruption of the higher-level data transfer services.

12.2.4.3 Consistent set of performance indicators

12.2.4.3.1 Consistent set of PIs preferential for RTE communications

Table 160 shows one of a consistent set of the performance indicators for CP 11/1. The values in Table 160 are representing one of the practical example, but not of the theoretical maximum, and the example is preferential for the RTE communications, which means that the total available bandwidth both for the RTE communications and the non-RTE communications is allocated alone to the RTE communications.

Table 160 – CP 11/1: Consistent set of PIs preferential for RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 2 ms DT_M = 20 ms DT_L = 200 ms	–
Number of end-stations	24	Maximum distance between nodes is 4 km
Number of switches between end-stations	0	3 hubs
Throughput RTE	Total = 7,3 Moctets/s TR_{HS} = 6,4 Moctets/s TR_{MS} = 0,9 Moctets/s	DV_{HS} = 12 800 octets DV_{MS} = 19 200 octets DV_L = 0 octets
Non-RTE bandwidth	0 %	–
Non-time-based synchronization accuracy	< 10 µs	–
Redundancy recovery time	0 s	–

12.2.4.3.2 Consistent set of PIs for RTE and non-RTE communications

Table 161 shows one consistent set of performance indicators for CP 11/1. The values given in Table 161 are representing one practical example, but they are not the theoretical maximum. The total available bandwidth is partitioned between the RTE communications and the non-RTE communications.

Table 161 – CP 11/1: Consistent set of PIs both for RTE and non-RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 2 ms DT_M = 20 ms DT_L = 200 ms	–
Number of end-stations	13	Maximum distance between nodes is 4 km
Number of switches between end-stations	0	5 hubs
Throughput RTE	Total = 5,7 Moctets/s TR_{HS} = 5,1 Moctets/s TR_{MS} = 0,6 Moctets/s	DV_{HS} = 10 240 octets DV_{MS} = 12 800 octets DV_L = 0 octets
Non-RTE bandwidth	< 20 %	–
Non-time-based synchronization accuracy	< 10 µs	–
Redundancy recovery time	0 s	–

12.3 Profile 11/2

12.3.1 Physical layer

The physical layer of 100 Mbit/s shall be according to ISO/IEC/IEEE 8802-3.

Connectors and cables are specified in IEC 61784-5-11 and IEC 61918.

12.3.2 Data-link layer

12.3.2.1 DLL services selection

The DLL service selection is the same as specified in 12.2.2.1.

12.3.2.2 DLL protocol selection

Table 162 specifies the DLL protocol selection within IEC 61158-4-11.

Table 162 – CP 11/2: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms, definitions, symbols and abbreviations	Partial	–
4	Overview of the DL-protocol	–	–
4.1	General	YES	–
4.2	Overview of the medium access control	YES	–
4.3	Service assumed from the PhL	YES	–
4.4	DLL architecture	–	–
4.4.1	Overview	YES	–
4.4.2	Star-architecture	NO	–
4.4.3	Loop-architecture	YES	–
4.5	Access control machine and schedule support functions	YES	–
4.6	Local parameters, variables, counters, timers and queues	–	–
4.6.1	Overview	YES	–
4.6.1.1	General	YES	–
4.6.1.2	Summary of variables, parameters, counters, timers for star-architecture	NO	–
4.6.1.3	Summary of variables, parameters, counters, timers for loop-architecture	YES	Relevant values and features to 100 Mbit/s data rate
4.6.2	Type 11 common variables, parameters, counters, timers and queues	YES	Relevant values and features to 100 Mbit/s data rate
4.6.3	Star-architecture specific variables, parameters, counters timers and queues	NO	–
4.6.4	Loop-architecture specific variables, parameters, counters timers and queues	YES	Relevant values and features to 100 Mbit/s data rate
5	General structure and encoding of PhIDEs and DLPDU and related element of procedure	YES	See Table 163
6	DLPDU-specific structure, encoding and elements of procedure	YES	See Table 164
7	DLE element of procedure	–	–
7.1	DLE elements of procedure for star-architecture	NO	–
7.2	DLE elements of procedure for loop-architecture	–	–
7.2.1	Overall structure	YES	–
7.2.2	Initialization	YES	–
7.2.3	Cyclic transmission TX/RX control (CTRC)	YES	Relevant values and features to 100 Mbit/s data rate
7.2.4	Sporadic TX/RX control (STRC)	YES	–
7.2.5	Access control machine (ACM)	YES	Table 75 applicable
7.2.6	Redundancy medium control (RMC)	YES	Table 83 applicable
7.3	Serializer and deserializer	YES	–
7.4	DLL management protocol	–	–
7.4.1	DLL management protocol for star-architecture	NO	–
7.4.2	DLL management protocol for loop-architecture	YES	–

Table 163 – CP 11/2: DLL protocol selection of Clause 5

Clause	Header	Presence	Constraints
5.1	Overview	YES	–
5.2	PhIDU structure and encoding	YES	–
5.3	Common MAC frame structure, encoding and elements of procedure	YES	–
5.4	Elements of the MAC frame	–	–
5.4.1	General	YES	–
5.4.2	Preamble field	YES	–
5.4.3	Start frame delimiter (SFD)	YES	–
5.4.4	Address field	YES	–
5.4.5	Length/type field	YES	–
5.4.6	Frame control field (FC)	–	–
5.4.6.1	Structure of FC field	YES	–
5.4.6.2	Frame type (F-type) field	YES	–
5.4.6.3	Priority field (Pri)	YES	Relevant feature to 100 Mbit/s data rate
5.4.7	Source node number field (SN)	YES	–
5.4.8	Data and pad field	YES	–
5.4.9	Frame check sequence (FCS)	YES	–
5.5	Order of bit transmission	YES	–
5.6	Invalid DLPDU	YES	–

Table 164 – CP 11/2: DLL protocol selection of Clause 6

Clause	Header	Presence	Constraints
6.1	General	YES	–
6.2	Synchronization DLPDU (SYN)	–	–
6.2.1	General	YES	–
6.2.2	Structure of SYN DLPDU	YES	–
6.2.3	Parameters of SYN DLPDU	–	–
6.2.3.1	Transmission permits node number (PN)	YES	Relevant feature to 100 Mbit/s operation of loop architecture
6.2.3.2	Control word (CW)	–	–
6.2.3.2.1	CW for star-architecture	NO	–
6.2.3.2.2	CW for loop-architecture	YES	–
6.2.3.3	Slot time (ST)	YES	Relevant feature to 100 Mbit/s operation of loop architecture
6.2.3.4	High-speed transmission period (Th)	YES	–
6.2.3.5	Medium-speed transmission period (Tm)	YES	–
6.2.3.6	Sporadic message transmission target-token-rotation-time period (Ts)	NO	Relevant feature to 100 Mbit/s operation of loop architecture
6.2.3.7	Low-speed transmission period (Tl)	NO	–
6.2.3.8	Live list (LL)	YES	–
6.2.4	User data	YES	–
6.2.5	Sending SYN DLPDU	YES	–
6.2.6	Receiving SYN DLPDU	YES	–
6.3	Transmission complete DLPDU (CMP)	YES	Relevant feature to 100 Mbit/s operation of loop architecture
6.4	In-ring request DLPDU (REQ)	–	–

Clause	Header	Presence	Constraints
6.4.1	General	YES	–
6.4.2	Structure of REQ DLPDU	YES	–
6.4.3	Node mode – ESYN Parameter	NO	–
6.4.4	Recipient node number (RN) Parameter	YES	–
6.4.5	User data of REQ DLPDU	YES	–
6.4.6	Sending REQ DLPDU	YES	Relevant feature to 100 Mbit/s operation of loop architecture
6.4.7	Receiving REQ DLPDU	YES	–
6.5	Claim DLPDU (CLM)	–	–
6.5.1	General	YES	–
6.5.2	Structure of CLM DLPDU	YES	–
6.5.3	Parameter of CLM DLPDU	–	–
6.5.3.1	Residual counts of CLM DLPDU parameter (RC)	YES	–
6.5.3.2	Slot time (ST) parameter	YES	Relevant feature to 100 Mbit/s operation of loop-architecture
6.5.3.3	Node mode (NM) parameter	NO	–
6.5.4	User data of CLM DLPDU	YES	–
6.5.5	Sending and receiving CLM DLPDU	YES	–
6.6	Command DLPDU (COM)	–	–
6.6.1	General	YES	–
6.6.2	Structure of COM DLPDU	YES	–
6.6.3	Parameters of COM DLPDU	YES	–
6.6.4	User data of COM DLPDU	YES	–
6.6.5	Sending and receiving COM DLPDU	YES	Relevant feature to 100 Mbit/s operation of loop-architecture
6.7	Cyclic data and cyclic data with transmission complete DLPDU (DT) and (DT-CMP)	–	–
6.7.1	General	YES	–
6.7.2	Structure of DT DLPDU	YES	–
6.7.3	Parameters of DT DLPDU	YES	–
6.7.3.1	DLCEP-address parameter	YES	–
6.7.3.2	Word length parameter (WD)	–	–
6.7.3.2.1	WD for star-architecture	NO	–
6.7.3.2.2	WD for loop-architecture	YES	Relevant feature to 100 Mbit/s operation of loop-architecture
6.7.4	Sending DT or DT-CMP DLPDU	YES	–
6.7.5	Receiving DT or DT-CMP DLPDU	YES	–
6.8	RAS DLPDU (RAS)	YES	–
6.8.1	General	–	–
6.8.2	Structure of RAS DLPDU	YES	–
6.8.3	DCEP-address parameters	YES	–
6.8.4	User data	YES	–
6.8.5	Sending and receiving RAS DLPDU	YES	Relevant feature to 100 Mbit/s operation of loop-architecture
6.9	Loop repeat request DLPDU (LRR)	YES	–
6.10	Loop diagnosis DLPDU (LPD)	YES	–

12.3.3   Application layer

12.3.3.1   AL service selection

The AL service selection is the same as specified in 12.2.3.1.

12.3.3.2   AL protocol selection

The AL protocol selection is the same as specified in 12.2.3.2.

12.3.4   Performance indicator selection

12.3.4.1   Performance indicator overview

Table 165 shows the performance indicators overview of CP 11/2.

Table 165 – CP 11/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end stations	YES	–
Basic network topology	YES	Loop (ring) topology
Number of switches between end stations	NO	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	IEC 61588 shall be installed
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	4 x Th

12.3.4.2   Performance indicator dependencies

12.3.4.2.1   Dependency matrix

Table 166 shows the dependencies between performance indicators for CP 11/2.

Table 166 – CP 11/2: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy	Non time-based synchronization accuracy	Redundancy recovery time
Delivery time		NO 12.3.4.2.2 12.3.4.2.3	NO 12.2.4.2.5	NO 12.3.4.2.2 12.3.4.2.3	NO 12.3.4.2.2 12.3.4.2.3	NO	NO	NO 12.3.4.2.6
Number of end stations	NO		NO	YES 12.3.4.2.2 12.3.4.2.3	YES 12.3.4.2.2 12.3.4.2.3	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO	NO
Throughput RTE	YES 12.3.4.2.2 12.3.4.2.3	YES 12.3.4.2.2 12.3.4.2.3	NO		YES 12.3.4.2.2 12.3.4.2.3	NO	NO	NO
Non-RTE bandwidth	YES 12.3.4.2.2 12.3.4.2.3	YES 12.3.4.2.2 12.3.4.2.3	NO	YES 12.3.4.2.2 12.3.4.2.3		NO	NO	NO
Time synchronization accuracy	NO	NO	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	NO	NO	NO	NO	NO		NO
Redundancy recovery time	YES 12.3.4.2.6	NO	NO	NO	NO	NO	NO	

12.3.4.2.2 Calculation of Delivery time

Delivery time is definitely specified by the application users using the TCC data service, and the delivery time specified meets both cases of no transmission error and one lost frame with recovery.

The TCC data service provides 2 kinds of data transmission services at the same time, that are according to the data preference and the delivery time of the APDU to be transferred using the data transmission service.

Table 167 specifies the TCC data service selection supported by this profile.

Table 167 – CP 11/2: TCC data service selection

Service ref.	Service name	Applicable	Constraint
IEC 61158-3-11 Clause 4	High-speed cyclic data transmission	YES	The range of the high-speed transmission period (T_h) is 1 ms to 160 ms, of which unit is in 0,1 ms
IEC 61158-3-11 Clause 4	Medium-speed cyclic data transmission	YES	The range of the medium-speed transmission period (T_m) is 10 ms to 1 000 ms, of which unit is in 1 ms and in multiples of the T_h

The performance indicator delivery time is related to the amount of both RTE data and non-RTE data which are exchanged between the end stations, the number of the Ethernet frame that is used for the deterministic transmission scheduling, the signal propagation delay to the end station and the number of end stations.

The performance indicator delivery time can be calculated using the Formulae (40), (41), (42) and (43).

$$DT_H = T_h \tag{40}$$

$$DT_M = T_m \tag{41}$$

$$T_h = T_{RTE} + T_{NRT} + T_{SCH} + T_{PD} + T_{MAC} \tag{42}$$

$$T_{RTE} = T_{HS} + \frac{T_{MS}}{T_m} \times T_h \tag{43}$$

where

DT_H is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;

DT_M is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;

T_h is the high-speed transmission time period, and is the basic cycle_time (ct) for the TCC data service;

T_m is the medium-speed transmission time period;

T_{RTE} is the total sum of the frame transmit time, in which the frame of the Ethernet with the RTE data as a payload of a fixed length is sent out of the end station within the time period of T_h. The total volume of the RTE data and the bandwidth for the non-RTE data is specified by the application user;

T_{NRT} is the total sum of the frame transmit time, in which the frame with the non-RTE data as a payload is sent out of the end station within the time period of T_h and is used for the standard Ethernet application on sporadic basis;

T_{SCH} is the total sum of the frame transmit time, in which the frame is exchanged for the deterministic transmission scheduling between the end stations. The T_{SCH} includes both the time for the synchronization DLPDU and the multiple Transmission complete DLPDUs which are specified in the IEC 61158-4-11, Clause 6;

T_{PD} is the sum total of the signal propagation delay (pd) between the end stations. The T_{PD} depends on the cable propagation delay (cd) and the number of the end stations;

T_{MAC} is the time for the maintenance and control, in which a new end station is solicited to join and the periodic time operation is controlled;

T_{HS} is the total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data;

T_{MS} is the total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data.

12.3.4.2.3 Relation between throughput RTE and non-RTE bandwidth

Figure 10 shows an example of the relation between the throughput RTE and the non-RTE bandwidth in the case of a 100 Mbit/s physical layer. This profile supports the specification of a percentage of the bandwidth and/or the throughput which are used for the non-RTE and the RTE communications.
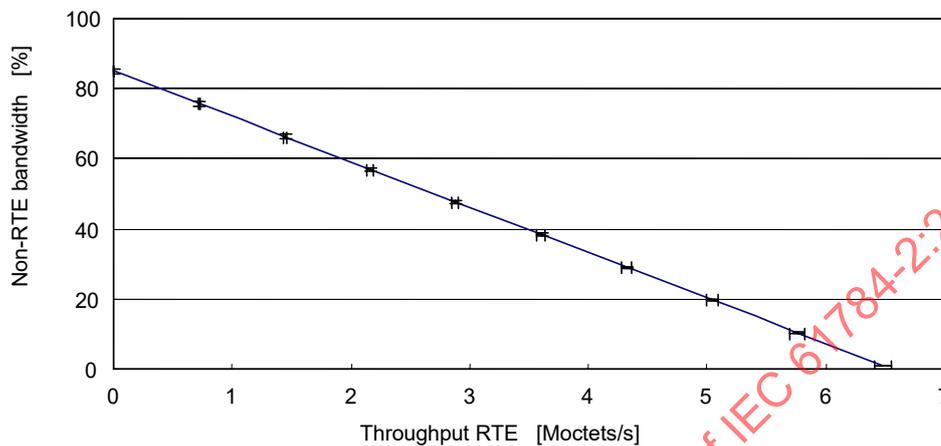
Figure 10 – CP 11/2: Throughput RTE and non-RTE bandwidth

The throughput RTE indicates the total amount of the APDU data by octet length per second, and the APDU data is sent out by the node using the TCC data service specified in IEC 61158-3-11, 4.3. The non-RTE bandwidth indicates the total percentage of the bandwidth, which is used for the non-RTE communications by the nodes using the sporadic message data service specified in the IEC 61158-3-11, 4.4.

The total bandwidth can be calculated using the Formulae (44), (45), (46), (47) and (48).

$$BW = BW_{RTE} + BW_{NRT} + BW_{CNT} \tag{44}$$

$$BW_{RTE} = TR_{RTE} \times \frac{8}{100} \tag{45}$$

$$TR_{RTE} = TR_{HS} + TR_{MS} \tag{46}$$

$$TR_{HS} = \frac{DV_{HS}}{DT_H} \tag{47}$$

$$TR_{MS} = \frac{DV_{MS}}{DT_M} \tag{48}$$

where

BW	is the total bandwidth in %, and the 100 % is 100 Mbit/s;
BW_{RTE}	is the bandwidth used for the RTE communications in %;
BW_{NRT}	is the bandwidth used for the non-RTE communications in %;
BW_{CNT}	is the bandwidth used for the scheduling communications and for the protocol overhead in %;
TR_{RTE}	is the throughput RTE in Moctets/s;
TR_{HS}	is the throughput RTE for the high-speed cyclic data in Moctets/s;
TR_{MS}	is the throughput RTE for the medium-speed cyclic data in Moctets/s;
DV_{HS}	is the total volume of the high-speed cyclic data sent by all end stations;
DV_{MS}	is the total volume of the medium-speed cyclic data sent by all end stations;
DT_H	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_M	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC.

The throughput RTE or the non-RTE bandwidth depends on the BW_{CNT} for scheduling the communications and for the protocol overhead. The scheduling communications and the protocol overhead, based on the formulae provided in 12.3.4.2.2, depend on the cable propagation delay and the total number of the end stations and is related to the time for the maintenance and control in order to solicit a new end station and to keep the periodic time operation.

12.3.4.2.4   Number of end-station

The maximum number of end stations shall be up to 254.

12.3.4.2.5   Basic network topology

The network topology supported by this profile is of a loop (ring).

12.3.4.2.6   Redundancy recovery time

The maximum time from a failure to become fully operational again in case of a single permanent failure is 4 x T_h (T_h: the high-speed transmission time period) in 12.3.4.2.2.

12.3.4.3   Consistent set of performance indicators

12.3.4.3.1   Consistent set of PIs preferential for RTE communications

Table 168 shows one of a consistent set of the performance indicators for CP 11/2. The values in Table 168 are representing one practical example, but not the theoretical maximum. The example is preferential for RTE communications, which means that the total available bandwidth both for the RTE communications and the non-RTE communications is allocated alone to the RTE communications.

Table 168 – CP 11/2: Consistent set of PIs preferential for RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 2 ms DT_M = 20 ms	–
Number of end stations	24	Total length of cables in a loop is 2 km
Number of switches between end stations	0	Not applicable
Throughput RTE	Total = 4,6 Moctets/s TR_{HS} = 4,0 Moctets/s TR_{MS} = 0,6 Moctets/s	DV_{HS} = 7 920 octets DV_{MS} = 11 520 octets
Non-RTE bandwidth	0 %	–
Non-time-based synchronization accuracy	< 10 μs	–
Redundancy recovery time	8 ms	–

12.3.4.3.2 Consistent set of PIs for RTE and non-RTE communications

Table 169 shows one consistent set of performance indicators for CP 11/2. The values given in Table 169 are representing one practical example, but they are not the theoretical maximum. The total available bandwidth is partitioned between the RTE communications and the non-RTE communications.

Table 169 – CP 11/2: Consistent set of PIs both for RTE and non-RTE communications

Performance indicator	Value	Constraints
Delivery time	DT_H = 2 ms DT_M = 20 ms	–
Number of end stations	13	Total length of cables in a loop is 2 km
Number of switches between end stations	0	Not applicable
Throughput RTE	Total = 4,8 Moctets/s TR_{HS} = 4,3 Moctets/s TR_{MS} = 0,5 Moctets/s	DV_{HS} = 8 640 octets DV_{MS} = 10 080 octets
Non-RTE bandwidth	< 20 %	–
Non-time-based synchronization accuracy	< 10 μs	–
Redundancy recovery time	8 ms	–

12.4 Profile 11/3

12.4.1 Physical layer

The physical layer of 1 000 Mbit/s shall be according to ISO/IEC/IEEE 8802-3.

Connectors and cables are specified in IEC 61784–5–11 and IEC 61918.

12.4.2 Data-link layer

12.4.2.1 DLL services selection

The DLL service selection is the same as specified in 12.2.2.1.

12.4.2.2   DLL protocol selection

Table 170 specifies the DLL protocol selection within IEC 61158–4–11.

Table 170 – CP 11/3: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	–
2	Normative references	YES	Relevant reference only
3	Terms, definitions, symbols and abbreviations	Partial	–
4	Overview of the DL-protocol	–	–
4.1	General	YES	–
4.2	Overview of the medium access control	YES	–
4.3	Service assumed from the PhL	YES	–
4.4	DLL architecture	–	–
4.4.1	Overview	YES	–
4.4.2	Star-architecture	NO	–
4.4.3	Loop-architecture	YES	–
4.5	Access control machine and schedule support functions	YES	–
4.6	Local parameters, variables, counters, timers and queues	–	–
4.6.1	Overview	YES	–
4.6.1.1	General	YES	–
4.6.1.2	Summary of variables, parameters, counters, timers for star-architecture	NO	–
4.6.1.3	Summary of variables, parameters, counters, timers for loop-architecture	YES	Relevant values and features to 1 000 Mbit/s data rate
4.6.2	Type 11 common variables, parameters, counters, timers and queues	YES	Relevant values and features to 1 000 Mbit/s data rate
4.6.3	Star-architecture specific variables, parameters, counters timers and queues	NO	–
4.6.4	Loop-architecture specific variables, parameters, counters timers and queues	YES	Relevant values and features to 1 000 Mbit/s data rate
5	General structure and encoding of PhIDEs and DLPDU and related elements of procedure	YES	See Table 171
6	DLPDU-specific structure, encoding and elements of procedure	YES	See Table 172
7	DLE elements of procedure	–	–
7.1	DLE elements of procedure for star-architecture	NO	–
7.2	DLE elements of procedure for loop-architecture	–	–
7.2.1	Overall structure	YES	–
7.2.2	Initialization	YES	–
7.2.3	Cyclic transmission TX/RX control (CTRC)	YES	Relevant values and features to 1 000 Mbit/s data rate
7.2.4	Sporadic TX/RX control (STRC)	YES	–
7.2.5	Access control machine (ACM)	YES	Table 76 applicable
7.2.6	Redundancy medium control (RMC)	YES	Table 84 applicable
7.3	Serializer and deserializer	YES	–
7.4	DLL management protocol	–	–
7.4.1	DLL management protocol for star-architecture	NO	–
7.4.2	DLL management protocol for loop-architecture	YES	–

Table 171 – CP 11/3: DLL protocol selection of Clause 5

Clause	Header	Presence	Constraints
5.1	Overview	YES	–
5.2	PhIDU structure and encoding	YES	–
5.3	Common MAC frame structure, encoding and elements of procedure	YES	–
5.4	Elements of the MAC frame	–	–
5.4.1	General	YES	–
5.4.2	Preamble field	YES	–
5.4.3	Start frame delimiter (SFD)	YES	–
5.4.4	Address field	YES	–
5.4.5	Length/type field	YES	–
5.4.6	Frame control field (FC)	–	–
5.4.6.1	Structure of FC field	YES	–
5.4.6.2	Frame type (F-type) field	YES	–
5.4.6.3	Priority field (Pri)	YES	Relevent feature to 1 000 Mbit/s data rate
5.4.7	Source node number field (SN)	YES	–
5.4.8	Data and pad field	YES	–
5.4.9	Frame check sequence (FCS)	YES	–
5.5	Order of bit transmission	YES	–
5.6	Invalid DLPDU	YES	–

Table 172 – CP 11/3: DLL protocol selection of Clause 6

Clause	Header	Presence	Constraints
6.1	General	YES	–
6.2	Synchronization DLPDU (SYN)	–	–
6.2.1	General	YES	–
6.2.2	Structure of SYN DLPDU	YES	–
6.2.3	Parameters of SYN DLPDU	–	–
6.2.3.1	Transmission permits node number (PN)	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.2.3.2	Control word (CW)	–	–
6.2.3.2.1	CW for star-architecture	NO	–
6.2.3.2.2	CW for loop-architecture	YES	–
6.2.3.3	Slot time (ST)	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.2.3.4	High-speed transmission period (Th)	YES	–
6.2.3.5	Medium-speed transmission period (Tm)	YES	–
6.2.3.6	Sporadic message transmission target-token-rotation-time period (Ts)	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.2.3.7	Low-speed transmission period (Tl)	YES	–
6.2.3.8	Live list (LL)	YES	–
6.2.4	User data	YES	–
6.2.5	Sending SYN DLPDU	YES	–
6.2.6	Receiving SYN DLPDU	YES	–
6.3	Transmission complete DLPDU (CMP)	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.4	In-ring request DLPDU (REQ)	–	–
6.4.1	General	YES	–
6.4.2	Structure of REQ DLPDU	YES	–
6.4.3	Node mode – ESYN parameter	YES	–
6.4.4	Recipient node number (RN) parameter	YES	–
6.4.5	User data of REQ DLPDU	YES	–
6.4.6	Sending REQ DLPDU	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.4.7	Receiving REQ DLPDU	YES	–
6.5	Claim DLPDU (CLM)	–	–
6.5.1	General	YES	–
6.5.2	Structure of CLM DLPDU	YES	–
6.5.3	Parameter of CLM DLPDU	–	–
6.5.3.1	Residual counts of CLM DLPDU parameter (RC)	YES	
6.5.3.2	Slot time (ST) parameter	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.5.3.3	Node mode (NM) parameter	YES	–
6.5.4	User data of CLM DLPDU	YES	–
6.5.5	Sending and receiving CLM DLPDU	YES	–

Clause	Header	Presence	Constraints
6.6	Command DLPDU (COM)	–	–
6.6.1	General	YES	–
6.6.2	Structure of COM DLPDU	YES	–
6.6.3	Parameter of COM DLPDU	YES	–
6.6.4	User data of COM DLPDU	YES	–
6.6.5	Sending and receiving COM DLPDU	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.7	Cyclic data and cyclic data with transmission complete DLPDU (DT) and (DT-CMP)	–	–
6.7.1	General	YES	–
6.7.2	Structure of the DT DLPDU	YES	–
6.7.3	Parameters of DT DLPDU	YES	–
6.7.3.1	DLCEP-address parameter	YES	–
6.7.3.2	Word length parameter (WD)	–	–
6.7.3.2.1	WD for star-architecture	NO	–
6.7.3.2.2	WD for loop-architecture	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.7.4	Sending DT or DT-CMP DLPDU	YES	–
6.7.5	Receiving DT or DT-CMP DLPDU	YES	–
6.8	RAS DLPDU (RAS)	–	–
6.8.1	General	YES	–
6.8.2	Structure of RAS DLPDU	YES	–
6.8.3	DCEP-address parameters	YES	–
6.8.4	User data	YES	–
6.8.5	Sending and receiving RAS DLPDU	YES	Relevant feature to 1 000 Mbit/s operation of loop-architecture
6.9	Loop repeat request DLPDU (LRR)	YES	–
6.10	Loop diagnosis DLPDU (LPD)	YES	–

12.4.3   Application layer

12.4.3.1   AL service selection

The AL service selection is the same as specified in 12.2.3.1.

12.4.3.2   AL protocol selection

The AL protocol selection is the same as specified in 12.2.3.2.

12.4.4   Performance indicator selection

12.4.4.1   Performance indicator overview

Table 173 shows the performance indicators ovewview of CP 11/3.

Table 173 – CP 11/3: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	–
Number of end stations	YES	–
Basic network topology	YES	Loop (ring) topology
Number of switches between end stations	NO	–
Throughput RTE	YES	–
Non-RTE bandwidth	YES	–
Time synchronization accuracy	YES	IEC 61588 shall be installed
Non-time-based synchronization accuracy	YES	–
Redundancy recovery time	YES	4 x Th

12.4.4.2 Performance indicator dependencies

12.4.4.2.1 Dependency matrix

Table 174 shows the dependencies between performance indicators for CP 11/3.

Table 174 – CP 11/3: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end- stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy	Non time-based synchronization accuracy	Redundancy recovery time
Delivery time		NO 12.4.4.2.2 12.4.4.2.3	NO 12.4.4.2.5	NO 12.4.4.2.2 12.4.4.2.3	NO 12.4.4.2.2 12.4.4.2.3	NO	NO	NO 12.4.4.2.6
Number of end stations	NO		NO	YES 12.4.4.2.2 12.4.4.2.3	YES 12.4.4.2.2 12.4.4.2.3	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO	NO
Throughput RTE	YES 12.4.4.2.2 12.4.4.2.3	YES 12.4.4.2.2 12.4.4.2.3	NO		YES 12.4.4.2.2 12.4.4.2.3	NO	NO	NO
Non-RTE bandwidth	YES 12.4.4.2.2 12.4.4.2.3	YES 12.4.4.2.2 12.4.4.2.3	NO	YES 12.4.4.2.2 12.4.4.2.3		NO	NO	NO
Time synchronization accuracy	NO	NO	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	NO	NO	NO	NO	NO		NO
Redundancy recovery time	YES 12.4.4.2.6	NO	NO	NO	NO	NO	NO	

12.4.4.2.2 Calculation of Delivery time

Delivery time is definitely specified by the application users using the TCC data service, and the delivery time specified meets both cases of no transmission error and one lost frame with recovery.

The TCC data service provides 3 kinds of the data transmission service at the same time, that are according to the data preference and the delivery time of an APDU to be transferred using the data transmission service.

Table 175 specifies the TCC data service selection supported by this profile.

Table 175 – CP 11/3: TCC data service selection

Service ref.	Service name	Applicable	Constraint
IEC 61158-3-11 Clause 4	High-speed cyclic data transmission	YES	The range of the high-speed transmission period (T_h) is 0,1 ms to 160 ms, of which unit is in 0,1 ms
IEC 61158-3-11 Clause 4	Medium-speed cyclic data transmission	YES	The range of the medium-speed transmission period (T_m) is 1 ms to 1 000 ms, of which unit is in 1 ms and in multiples of the T_h
IEC 61158-3-11 Clause 4	Low-speed cyclic data transmission	YES	The range of low-speed transmission period (T_l) is 1 ms to 10 000 ms, of which unit is in 1 ms and in multiples of the T_h

The performance indicator delivery time is related to the amount of both RTE data and non-RTE data which are exchanged between the end-stations, the number of the Ethernet frame that is used for the deterministic transmission scheduling, the signal propagation delay to the end-station, the number of the end-staions.

The performance indicator delivery time can be calculated using the Formulae (49), (50), (51), (52) and (53).

$$DT_H = T_h \tag{49}$$

$$DT_M = T_m \tag{50}$$

$$DT_L = T_l \tag{51}$$

$$T_h = T_{RTE} + T_{NRT} + T_{SCH} + T_{PD} + T_{MAC} \tag{52}$$

$$T_{RTE} = T_{HS} + \frac{T_{MS}}{T_m} \times T_h + \frac{T_{LS}}{T_l} \times T_h \tag{53}$$

where

| DT_H | is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC; |

| DT_M | is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC; |

| DT_L | is the delivery time for the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC; |

| T_h | is the high-speed transmission time period, and is the basic cycle_time (ct) for the TCC data service; |

| T_m | is the medium-speed transmission time period; |

| T_l | is the low-speed transmission time period; |

| T_{RTE} | is the total sum of the frame transmit time, in which the frame of the Ethernet with the RTE data as a payload of a fixed length is sent out of the end-station within the time period of T_h. The total volume of the RTE data and the bandwidth for the non-RTE data is specified by the application user; |

| T_{NRT} | is the total sum of the frame transmit time, in which the frame with the non-RTE data as a payload is sent out of the end-station within the time period of T_h and is used for the standard Ethernet application on sporadic basis; |

| T_{SCH} | is the total sum of the frame transmit time, in which the frame is exchanged for the deterministic transmission scheduling between the end-stations. The T_{SCH} includes both the time for the synchronization DLPDU and the multiple transmission complete DLPDUs which are specified in the IEC 61158-4-11, Clause 6; |

| T_{PD} | is the sum total of the signal propagation delay (pd) between the end-stations. The T_{PD} depends on the cable propagation delay (cd) and the number of the end-stations; |

| T_{MAC} | is the time for the maintenance and control, in which a new end-station is solicited to join and the periodic time operation is controlled; |

| T_{HS} | is the total sum of the frame transmit time, in which the TCC data frame conveys the high-speed cyclic data; |

| T_{MS} | is the total sum of the frame transmit time, in which the TCC data frame conveys the medium-speed cyclic data; |

| T_{LS} | is the total sum of the frame transmit time, in which the TCC data frame conveys the low-speed cyclic data. |

12.4.4.2.3 Relation between throughput RTE and non-RTE bandwidth

Figure 11 shows an example of the relation between the throughput RTE and the non-RTE bandwidth in the case of 1 000 Mbit/s physical layer. This profile supports the specification of a percentage of the bandwidth and/or the rhtoughput which are used for the non-RTE and the RTE communications.
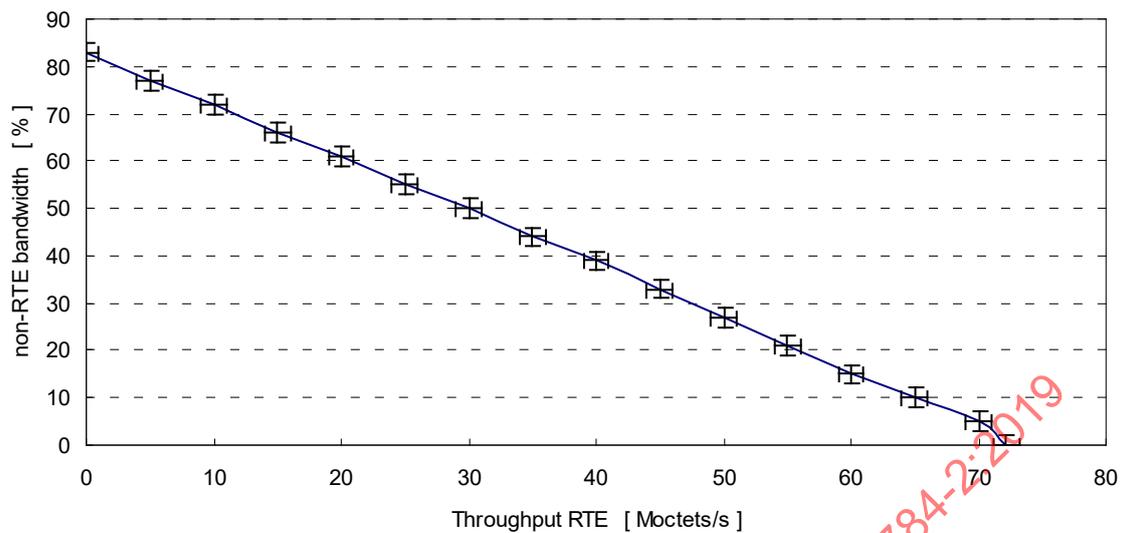
Figure 11 – CP 11/3: Throughput RTE and non-RTE bandwidth

The throughput RTE indicates the total amount of the APDU data by octet length per second, and the APDU data is sent out by the node using the TCC data service specified in the IEC 61158-3-11, 4.3. The non-RTE bandwidth indicates the total percentage of the bandwidth, which is used for the non-RTE communications by the nodes using the sporadic message data service specified in the IEC 61158–3–11, 4.4.

The total bandwidth can be calculated using the Formulae (54), (55), (56), (57), (58) and (59).

$$BW = BW_{RTE} + BW_{NRT} + BW_{CNT} \tag{54}$$

$$BW_{RTE} = TR_{RTE} \times \frac{8}{1000} \tag{55}$$

$$TR_{RTE} = TR_{HS} + TR_{MS} + TR_{LS} \tag{56}$$

$$TR_{HS} = \frac{DV_{HS}}{DT_H} \tag{57}$$

$$TR_{MS} = \frac{DV_{MS}}{DT_M} \tag{58}$$

$$TR_{LS} = \frac{DV_{LS}}{DT_L} \tag{59}$$

where

BW	is the total bandwidth in %, and the 100 % is 1 000 Mbit/s;
BW_{RTE}	is the bandwidth used for the RTE communications in %;
BW_{NRT}	is the bandwidth used for the non-RTE communications in %;
BW_{CNT}	is the bandwidth used for the scheduling communications and for the protocol overhead in %;
TR_{RTE}	is the throughput RTE in Moctets/s;
TR_{HS}	is the throughput RTE for the high-speed cyclic data in Moctets/s;
TR_{MS}	is the throughput RTE for the medium-speed cyclic data in Moctets/s;
TR_{LS}	is the throughput RTE for the low-speed cyclic data in Moctets/s;
DV_{HS}	is the total volume of the high-speed cyclic data sent by all end-stations;
DV_{MS}	is the total volume of the medium-speed cyclic data sent by all end-stations;
DV_{LS}	is the total volume of the low-speed cyclic data sent by all end-stations;
DT_H	is the delivery time for the high-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_M	is the delivery time for the medium-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC;
DT_L	is the delivery time for the low-speed cyclic data, which includes both the sender stack traversal time (STTs) and the receiver stack traversal time (STTr) including Phy and MAC.

The throughput RTE or the non-RTE bandwidth depends on the BW_{CNT} for scheduling the communications and for the protocol overhead. The scheduling communications and the protocol overhead, based on the formulas provided in 12.4.4.2.2, the cable propagation delay and the total number of the end-stations, and is related to the time for the maintenance and control in order to solicit a end-stations and to keep the periodic time operation.

12.4.4.2.4   Number of end station

The maximum number of the end-stations shall be up to 254.

12.4.4.2.5   Basic network topology

The network topology supported by this profile is of a loop (ring).

12.4.4.2.6   Redundancy recovery time

The maximum time from a failure to become fully operational again in case of a single permanent failure is 4 x T_h (T_h: the high-speed transmission time period) in 12.4.4.2.2.

12.4.4.3   Consistent set of performance indicators

12.4.4.3.1   Consistent set of PIs preference for RTE communications

Table 176 shows one of a consistent set of the performance indicators for CP 11/3. The values in Table 176 are representing one of the practical example, but not of the theoretical maximum, and the example is preferential for the RTE communications, which means that the total available bandwidth both for the RTE communications and the non-RTE communications is allocated alone to the RTE communications.

**Table 176 – CP 11/3: Consistent set of PIs preferential
for RTE communications**

Performance indicator	Value	Constraints
Delivery time	DT_H = 1 ms DT_M = 10 ms DT_L = 100 ms	–
Number of end-stations	32	Total length of cables in a loop is 6 km
Number of switches between end-stations	0	Not aaplicable
Throughput RTE	Total = 72,2 Moctets/s TR_{HS} = 59,9 Moctets/s TR_{MS} = 12,0 Moctets/s TR_{LS} = 0,3 Moctets/s	DV_{HS} = 59 904 octets DV_{MS} = 119 808 octets DV_{LS} = 299 520 octets
Non-RTE bandwidth	0 %	–
Non-time-based synchronization accuracy	< 10 µs	–
Redundancy recovery time	4 ms	–

12.4.4.3.2   Consistent set of PIs for RTE and non-RTE communications

Table 177 shows one consistent set of performance indicators for CP 11/3. The values given in Table 177 are representing one practical example, but they are not the theoretical maximum. The total available bandwidth is partitioned between the RTE communications and the non-RTE communications.

**Table 177 – CP 11/3: Consistent set of PIs both for RTE
and non-RTE communications**

Performance indicator	Value	Constraints
Delivery time	DT_H = 1 ms DT_M = 10 ms DT_L = 100 ms	–
Number of end-stations	32	Total length of cables in a loop is 6 km
Number of switches between end-stations	0	Not applicable
Throughput RTE	Total = 56,9 Moctets/s TR_{HS} = 48,6 Moctets/s TR_{MS} = 6,4 Moctets/s TR_{LS} = 1,9 Moctets/s	DV_{HS} = 48 640 octets DV_{MS} = 64 000 octets DV_{LS} = 192 000 octets
Non-RTE bandwidth	> 20 %	–
Non-time-based synchronization accuracy	< 10 µs	–
Redundancy recovery time	4 ms	–

13 Communication Profile Family 12 (EtherCAT®) – RTE communication profiles

13.1 General overview

EtherCAT® [11] is a Real-Time Ethernet technology based on ISO/IEC/IEEE 8802-3, IEC 61158-2, IEC 61158-3-12, IEC 61158-4-12, IEC 61158-5-12 and IEC 61158-6-12 especially suitable for communication between control systems and peripheral devices like I/O systems, drives, sensors and actuators.

In this document, the following communication profiles are specified for CPF 12:

– Profile 12/1

  This profile defines protocol and service selections for simple I/O devices which may communicate process data cyclically.

– Profile 12/2

  This profile defines protocol and service selections for two types of devices:

  • smart or modular devices with mailbox communication capabilities;

  • such devices that additionally support time based synchronization for performing tightly coordinated actions.

All three types of devices can be mixed arbitrarily.

13.2 Profile CP 12/1

13.2.1 Physical layer

The physical layer is described in IEC 61158-2 and ISO/IEC/IEEE 8802-3:2017. Table 178 specifies the use of the preferred physical layer, specified in ISO/IEC/IEEE 8802-3:2017, included in this profile.

Table 179 specifies the use of an optimized physical layer for backplane applications, specified in of IEC 61158-2, included in this profile.

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[11] EtherCAT® is a registered trade name of Beckhoff, Verl. This information is given for the convenience of users of this document and does not constitute an endorsement by the IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name EtherCAT. Use of the trade name EtherCAT requires permission from the trade name holder.

**Table 178 – CP 12/1: PhL selection of preferred physical layer
from ISO/IEC/IEEE 8802-3:2017**

Clause	Header	Presence	Constraints
1	Introduction	YES	—
2	Media Access Control (MAC) service specification	YES	—
3	Media Access Control (MAC) frame and packet specifications	YES	—
4	Media Access Control	NO	—
5	Layer Management	Optional	—
6…20	--	NO	—
Annex 4A	Simplified full duplex media access control	YES	—
21	Introduction to 100 Mb/s baseband networks, type 100BASE-T	YES	—
22	Reconciliation Sublayer (RS) and Media Independent Interface (MII)	YES	—
23	Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 100BASE-T4	NO	—
24	Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X	YES	—
25	Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-TX	Optional	Preferred technology
26	Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-FX	Optional	Use for specific environmental conditions
27	Repeater for 100 Mb/s baseband networks	NO	
28	Physical Layer link signaling for 10 Mb/s, 100 Mb/s, and 1 000 Mb/s Auto-Negotiation on twisted pair	Optional	Auto-negotiation and auto-crossover are highly recommended
29	System considerations for multisegment 100BASE-T networks	Optional	Link aggregation can be used but not recommended
30 … 32	--	NO	—
33	Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)	Optional	—
Annex 22A…D	MII	YES	—
Annex 23A…C	6T code words	NO	—
Annex 27A	Repeater delay consistency requirements	NO	—
Annex 28A…D	Selector Field definitions	YES	
Annex 29A…B	DTE and repeater delay components	Optional	—
Annex 30A…C	GDMO specification for IEEE 802.3 managed object classes	NO	—
Annex 31A…D	MAC Control opcode assignments	NO	—
Annex 32A	Use of cabling systems with nominal differential characteristic impedance of 120 Ω or 150 Ω	NO	—
Annex 33A	PSE-PD stability	NO	—
34 ff	Introduction to 1 000 Mb/s baseband network	Optional	For future use

**Table 179 – CP 12/1: PhL selection of an optimized physical layer
from IEC 61158-2**

Clause	Header	Presence	Constraints
5	DLL – PhL interface	—	—
5.8	Type 12: Required services	YES	—
6	Systems management – PhL interface	—	—
6.7	Type 12: Systems management – PhL interface	YES	—
7	DCE independent sublayer (DIS)	—	—
7.6	Type 12: DIS	YES	—
8	DTE – DCE interface and MIS-specific functions	—	—
8.5	Type 12: DTE – DCE interface	YES	Interface not exposed
9	Medium dependent sublayer (MDS)	—	—
9.9	Type 12: Wire media	YES	—
10	MDS – MAU interface	—	—
29	Type 12: Medium attachment unit: electrical medium	YES	—

13.2.2 Data-link layer

13.2.2.1 EtherCAT Slave

Data-link layer is described in IEC 61158-3-12 and IEC 61158-4-12. Table 180 specifies the use of the services, specified in IEC 61158-3-12, included in this profile. Table 181 specifies the use of the protocol, specified in IEC 61158-4-12, included in this profile.

Table 180 – CP 12/1: DLL service selection

Clause	Header	Presence	Constraints
4	Data-link layer services and concepts	—	—
4.1	Operating principle	YES	—
4.2	Topology	YES	—
4.3	Data-link layer overview	YES	—
4.4	Error detection overview	YES	—
4.5	Parameter and process data handling introduction	Partial	Some examples are not describing mandatory functions
4.6	Node reference model	YES	—
4.7	Operation overview	Partial	Direct mode mandatory
4.8	Addressing	YES	—
4.9	Slave classification	Partial	Basic slave mandatory
4.10	Structure of the communication layer in the slave	Partial	—
5	Communication services	—	—
5.1	Overview	YES	—
5.2	Read services	Partial	Responder Services (.ind/.rsp)
5.3	Write services	Partial	Responder Services (.ind/.rsp)
5.4	Combined read/write services	Partial	Responder Services (.ind/.rsp)
5.5	Network services	NO	—
5.6	Mailbox	NO	—
6	Local interactions	—	—

Clause	Header	Presence	Constraints
6.1	Read Local	YES	—
6.2	Write Local	YES	—

Table 181 – CP 12/1: DLL protocol selection

Clause	Header	Presence	Constraints
4	Overview of the DL-protocol	—	—
4.1	Operating principle	YES	—
4.2	Topology	YES	—
4.3	Frame processing principles	YES	—
4.4	Data-link layer overview	YES	—
4.5	Error detection overview	YES	—
4.6	Node reference model	YES	—
4.7	Operation overview	Partial	Direct mode mandatory
5	Frame Structure	—	—
5.1	Frame coding principles	YES	—
5.2	Data types and encoding rules	Partial	Types needed for application and unsigned integer types
5.3	DL PDU structure	YES	—
5.4	Type 12 DLPDU structure	YES	—
5.5	Network variable structure	NO	—
5.6	Type 12 mailbox structure	NO	—
6	Attributes	—	—
6.1	Management	YES	—
6.2	Statistics	YES	—
6.3	Watchdogs	YES	—
6.4	Slave information interface	YES	—
6.5	Media independent interface (MII)	YES	—
6.6	Fieldbus memory management unit (FMMU)	YES	—
6.7	Sync manager	NO	—
6.8	Distributed Clock	Partial	Timestamping of messages if more than 2 ports
7	DL-user memory	—	—
7.1	Overview	Optional	If mailbox supported
7.2	Mailbox access type	Optional	If mailbox supported
7.3	Buffered access type	Optional	—
8	Type 12:FDL Protocol state machines	—	—
8.1	Overview of slave DL state machines	Partial	Machines mandatory
8.2	State machine description	—	—
8.2.1	Port state machine (PSM)	YES	—
8.2.2	PDU handler state machine (DHSM)	YES	—
8.2.3	Synch manager state machine (SYMSM)	YES	—
8.2.4	Resilient Mailbox State Machine (RMSM)	Optional	If mailbox supported
8.2.5	SII State Machine (SIISM)	YES	—
8.2.6	MII State Machine (MIISM)	YES	—
8.2.7	DC State Machine (DCSM)	Partial	Timestamping of messages if more than 2 ports

13.2.2.2 EtherCAT Master

The data-link layer is described in IEC 61158-3-12 and IEC 61158-4-12. Table 182 specifies the use of the services, specified in IEC 61158-3-12, included in this profile. Table 183 specifies the use of the protocol, specified in IEC 61158-4-12, included in this profile. The selection of services used is up to the master. The Auto Increment Read and Write services are mandatory.

Table 182 – CP 12/1: DLL service selection

Clause	Header	Presence	Constraints
4	Data-link layer services and concepts	—	—
4.1	Operating principle	YES	—
4.2	Topology	YES	—
4.3	Data-link layer overview	YES	—
4.4	Error detection overview	YES	—
4.5	Parameter and process data handling introduction	Partial	Some example are not describing mandatory functions
4.6	Node reference model	YES	—
4.7	Operation overview	Partial	Direct mode mandatory
4.8	Addressing	YES	—
4.9	Slave classification	NO	—
4.10	Structure of the communication layer in the slave	Partial	—
5	Communication services	—	—
5.1	Overview	YES	—
5.2	Read services	Partial	Requestor Services (.req/.cnf)
5.3	Write services	Partial	Requestor Services (.req/.cnf)
5.4	Combined read/write services	Partial	Requestor Services (.req/.cnf)
5.5	Network services	NO	—
5.6	Mailbox	NO	—
6	Local interactions	—	—
6.1	Read local	YES	—
6.2	Write local	YES	—

Table 183 – CP 12/1: DLL protocol selection

Clause	Header	Presence	Constraints
4	Overview of the DL-protocol	—	—
4.1	Operating principle	YES	—
4.2	Topology	YES	—
4.3	Frame processing principles	YES	—
4.4	Data-link layer overview	YES	—
4.5	Error detection overview	YES	—
4.6	Node reference model	YES	—
4.7	Operation overview	Partial	Direct mode mandatory
5	Frame Sructure	—	—
5.1	Frame coding principles	YES	—
5.2	Data types and encoding rules	Partial	Types needed for application and unsigned integer types
5.3	DL PDU structure	YES	—
5.4	Type 12 DLPDU structure	YES	—
5.5	Network variable structure	NO	—
5.6	Type 12 mailbox structure	NO	—
6	Attributes	—	—
6.1	Management	YES	—
6.2	Statistics	YES	—
6.3	Watchdogs	YES	—
6.4	Slave information interface	YES	—
6.5	Media independent interface (MII)	YES	—
6.6	Fieldbus memory management unit (FMMU)	YES	—
6.7	Sync manager	YES	—
6.8	Distributed Clock	Partial	Timestamping of messages if more than 2 ports
7	DL-user memory	—	—
7.1	Overview	YES	—
7.2	Mailbox access type	YES	—
7.3	Buffered access type	YES	—
8	Type 12:FDL Protocol state machines	—	—
8.1	Overview of slave DL state machines	NO	—
8.2	State machine description	—	—
8.2.1	Port state machine (PSM)	NO	—
8.2.2	PDU handler state machine (DHSM)	NO	—
8.2.3	Synch manager state machine (SYMSM)	NO	—
8.2.4	Resilient Mailbox State Machine (RMSM)	NO	—
8.2.5	SII State Machine (SIISM)	NO	—
8.2.6	MII State Machine (MIISM)	NO	—
8.2.7	DC State Machine (DCSM)	NO	—

13.2.3 Application layer

13.2.3.1 EtherCAT Slave

The application layer is described in IEC 61158-5-12 and IEC 61158-6-12. Table 184 specifies the use of the services, specified in IEC 61158-5-12, included in this profile. Table 185 specifies the use of the protocol, specified in IEC 61158-6-12, included in this profile.

Table 184 – CP 12/1: AL service selection

Clause	Header	Presence	Constraints
4	Concepts	—	—
4.1	Common concepts	YES	—
4.2	Type specific concepts	—	—
4.2.1	Operating principle	YES	—
4.2.2	Communication model overview	YES	—
4.2.3	Application layer element description	YES	—
4.2.4	Slave reference model	YES	—
4.2.5	Master reference model	NO	—
5	Data Type ASE	YES	—
6	Communication model specification	—	—
6.1	ASEs	—	—
6.1.1	Process data ASE	YES	—
6.1.2	SII ASE	Partial	Mandatory objects, no categories required
6.1.3	Isochronous ASE	NO	—
6.1.4	CoE ASE	NO	—
6.1.5	EoE ASE	NO	—
6.1.6	FoE ASE	NO	—
6.1.7	MBX ASE	NO	—
6.2	AR	YES	—

Table 185 – CP 12/1: AL protocol selection

Clause	Header	Presence	Constraints
4	Application Layer protocol specification	—	—
4.1	Operating principle	YES	—
4.2	Node reference model	YES	—
5	FAL syntax description	—	—
5.1	Coding principles	YES	—
5.2	Data types and encoding rules	YES	—
5.3	AR coding	YES	No Bootstrap
5.4	SII coding	YES	—
5.5	Isochronous PDI coding	NO	—
5.6	CoE coding	NO	—
5.7	EoE coding	NO	—
5.8	FoE coding	NO	—
6	FAL protocol state machine	—	—

Clause	Header	Presence	Constraints
6.1	Overall structure	YES	—
6.2	AP-Context state machine	YES	—
6.3	FAL service protocol machine (FSPM)	YES	—
6.4	Application Relationship Protocol Machines (ARPMs)	—	—
6.4.1	AL state machine	YES	No Bootstrap and start mailbox required
6.4.2	Mailbox handler state machine	Optional	—
6.4.3	CoE state machine	NO	—
6.4.4	EoE state machine	NO	—
6.4.5	FoE state machine	NO	—
6.5	DLL mapping protocol machine (DMPM)	YES	—

13.2.3.2 EtherCAT master

The application layer is described in IEC 61158-5-12 and IEC 61158-6-12. Table 186 specifies the use of the services, specified in IEC 61158-5-12, included in this profile. Table 187 specifies the use of the protocol, specified in IEC 61158-6-12, included in this profile.

Table 186 – CP 12/1: AL service selection

Clause	Header	Presence	Constraints
4	Concepts	—	—
4.1	Common concepts	YES	—
4.2	Type specific concepts	—	—
4.2.1	Operating principle	YES	—
4.2.2	Communication model overview	YES	—
4.2.3	Application layer element description	YES	—
4.2.4	Slave reference model	NO	—
4.2.5	Master reference model	YES	—
5	Data Type ASE	YES	—
6	Communication model specification	—	—
6.1	ASEs	—	—
6.1.1	Process data ASE	YES	—
6.1.2	SII ASE	Partial	Mandatory objects, no categories required
6.1.3	Isochronous ASE	NO	—
6.1.4	CoE ASE	NO	—
6.1.5	EoE ASE	NO	—
6.1.6	FoE ASE	NO	—
6.1.7	MBX ASE	NO	—
6.2	AR	YES	—

Table 187 – CP 12/1: AL protocol selection

Clause	Header	Presence	Constraints
4	Application Layer protocol specification	—	—
4.1	Operating principle	YES	—
4.2	Node reference Model	YES	—
5	FAL syntax description	—	—
5.1	Coding principles	YES	—
5.2	Data types and encoding rules	YES	—
5.3	AR coding	YES	No Bootstrap
5.4	SII coding	YES	—
5.5	Isochronous PDI coding	NO	—
5.6	CoE coding	NO	—
5.7	EoE coding	NO	—
5.8	FoE coding	NO	—
6	FAL protocol state machine	—	—
6.1	Overall structure	YES	—
6.2	AP-Context state machine	YES	—
6.3	FAL service protocol machine (FSPM)	YES	—
6.4	Application Relationship Protocol Machines (ARPMs)	—	—
6.4.1	AL state machine	NO	—
6.4.2	Mailbox handler state machine	NO	—
6.4.3	CoE state machine	NO	—
6.4.4	EoE state machine	NO	—
6.4.5	FoE state machine	NO	—
6.5	DLL mapping protocol machine (DMPM)	YES	—

13.2.4 Performance indicator selection

13.2.4.1 Performance indicator overview

Table 188 gives an overview of the performance indicator usage.

Table 188 – CP 12/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	—
Number of switches between end-stations	NO	Slave device includes switch functionality
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	NO	—
Non-time-based synchronization accuracy	YES	—
Redundancy recovery time	Optional	—

13.2.4.2 Performance indicator dependencies

Table 189 specifies the dependencies of the performance indicators (row) from the performance indicators (column).

Table 189 – CP 12/1: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Non-time-based synchronization accuracy	Redundancy recovery time
Delivery time		YES 13.2.4.4	NO	YES 13.2.4.5	NO	NO	YES 13.2.4.6
Number of end-stations	NO		NO	NO	NO	YES 13.2.4.7	NO
Basic network topology	NO	NO		NO	NO	NO	YES 13.2.4.8
Throughput RTE	NO	NO	NO		YES 13.2.4.9	NO	NO
Non-RTE bandwidth	NO	NO	NO	YES 13.2.4.9		NO	NO
Non-time-based synchronization accuracy	NO	YES 13.2.4.7	NO	NO	NO		NO
Redundancy recovery time	NO	NO	YES 13.2.4.8	NO	NO	NO	

Table 190 gives an outline of the range of performance indicators.

Table 190 – CP 12/1: PI ranges

Performance indicator	Value	Explanation
Delivery time	20 µs – 1 s	—
Number of end-stations	Up to 65 535	—
Number of switches between end-stations	Not practically limited by the protocol	EtherCAT slaves are 2-port switches
Throughput RTE	1 % – 100 %	—
Non-RTE bandwidth	99 % – 0 %	—
Non-time-based synchronization accuracy	1 µs – 10 µs	Depends upon topology
Redundancy recovery time	1 cycle	—

13.2.4.3 Calculation of delivery time

The performance indicator delivery time can be calculated by Formula (60).

$$t_D = t_{cycle} + t_{data} + t_{cd} \times l_{tc} + \sum_{i=1}^{NoS} t_{pd}(i) + t_{cpdl} \tag{60}$$

where

t_D	is the delivery time;
t_{cycle}	is the cycle time ($t_{cycle} \geq t_{data}$);
t_{data}	is the time to transmit the longest Real-time Ethernet frame (80 ns/octet);
t_{cd}	is the cable delay (4,5 – 5 ns/m);
l_{tc}	is the total cable length in m;
Pd	is the propagation delay of a slave (implementation dependent);
NoS	is the number of slaves;
t_{cpdl}	is the data copy delay within a slave (typical value: < 100 ns).

The cycle time is independent from the propagation delay of the connected slaves and from the cable delays, since the full-duplex capabilities of the system allow to send the next frame before the initial frame has returned to the master device. The minimum cycle time thus is only limited by the transmission time of the longest RTE frame in the given application scenario. The master implementation may further restrict this minimum cycle time.

13.2.4.4 Delivery time dependency on number of end-stations

The number of end-stations typically influences the amount of data, thus the time to transmit the data frame as well as the sum of propagation delays and hence the delivery time as described in Formula (60).

13.2.4.5 Delivery time dependency on throughput RTE

The delivery time depends on throughput RTE via data and cycle time, since throughput RTE can be adapted primarily by changing these two parameters. If throughput RTE is increased by increasing the amount of data without changing the cycle time, the delivery time is increased, too. If throughput RTE is increased by reducing the cycle time, the delivery time is reduced. If throughput RTE is increased by changing both parameters accordingly, the delivery time is not influenced as described in Formula (60).

13.2.4.6 Delivery time dependency on redundancy recovery time

Redundancy recovery time influences the cycle time and hence the delivery time as described in Formula (60).

13.2.4.7 Relation between number of end-stations and non-time-based synchronization accuracy

Number of end-stations influences the non-time-based synchronization accuracy and vice versa.

13.2.4.8 Relation between basic network topology and redundancy recovery time

Since cable redundancy determines the topology as such, the requirement for a finite redundancy recovery time influences the basic network topology and vice versa.

13.2.4.9 Relation between throughput RTE and non-RTE bandwidth

The non-RTE bandwidth is the difference between overall bandwidth and the RTE throughput (RTE overhead included) hence both values influence each other.

13.2.4.10 Consistent set of performance indicators for mid size automation system

Table 191 gives an outline of a consistent set of performance indicators for CP 12/1 for mid size automation systems with a cycle time of 60 µs.

Table 191 – CP 12/1: Consistent set of PIs for mid size automation systems

Performance indicator	Value	Constraints
Delivery time	< 150 µs	Without failure
Number of end-stations	180	—
Number of switches between end-stations	NA	—
Throughput RTE	10 750 000 octets/s	—
Non-RTE bandwidth	50,6 %	—
Non-time-based synchronization accuracy	10 µs	—
Redundancy recovery time	60 µs	—

13.3 Profile CP 12/2

13.3.1 Physical layer

The physical layer is the same as described in 13.2.1.

13.3.2 Data-link layer

13.3.2.1 EtherCAT Slave

The data-link layer is described in IEC 61158-3-12 and 61158-4-12. Table 192 specifies the use of the services, specified in IEC 61158-3-12, included in this profile. Table 193 specifies the use of the protocol, specified in IEC 61158-4-12, included in this profile.

Table 192 – CP 12/2: DLL service selection

Clause	Header	Presence	Constraints
4	Data-link layer services and concepts	—	—
4.1	Operating principle	YES	—
4.2	Topology	YES	—
4.3	Data-link layer overview	YES	—
4.4	Error detection overview	YES	—
4.5	Parameter and process data handling introduction	Partial	Some example are not describing mandatory functions
4.6	Node reference model	YES	—
4.7	Operation overview	Partial	Direct mode mandatory
4.8	Addressing	YES	—
4.9	Slave classification	Partial	Basic slave mandatory
4.10	Structure of the communication layer in the slave	YES	—
5	Communication services	—	—
5.1	Overview	YES	—
5.2	Read services	Partial	Responder Services (.ind/.rsp)
5.3	Write services	Partial	Responder Services (.ind/.rsp)
5.4	Combined read/write services	Partial	Responder Services (.ind/.rsp)
5.5	Network services	NO	—

Clause	Header	Presence	Constraints
5.6	Mailbox	NO	—
6	Local interactions	—	—
6.1	Read local	YES	—
6.2	Write local	YES	—

Table 193 – CP 12/2: DLL protocol selection

Clause	Header	Presence	Constraints
4	Overview of the DL-protocol	—	—
4.1	Operating principle	YES	—
4.2	Topology	YES	—
4.3	Frame processing principles	YES	—
4.4	Data-link layer overview	YES	—
4.5	Error detection overview	YES	—
4.6	Node reference model	YES	—
4.7	Operation overview	Partial	Direct mode mandatory
5	Frame Sructure	—	—
5.1	Frame coding principles	YES	—
5.2	Data types and encoding rules	Partial	Types needed for application and unsigned integer types
5.3	DL PDU structure	YES	—
5.4	Type 12 DLPDU structure	YES	—
5.5	Network variable structure	NO	—
5.6	Type 12 mailbox structure	NO	—
6	Attributes	—	—
6.1	Management	YES	—
6.2	Statistics	YES	—
6.3	Watchdogs	YES	—
6.4	Slave information interface	YES	—
6.5	Media independent interface (MII)	YES	—
6.6	Fieldbus memory management unit (FMMU)	YES	—
6.7	Sync manager	YES	—
6.8	Distributed Clock	Optional	If time based synchronization is supported
7	DL-user memory	—	—
7.1	Overview	YES	—
7.2	Mailbox access type	YES	—
7.3	Buffered access type	YES	—
8	Type 12:FDL Protocol state machines	—	—
8.1	Overview of slave DL state machines	YES	—
8.2	State machine description	—	—
8.2.1	Port state machine (PSM)	YES	—
8.2.2	PDU handler state machine (DHSM)	YES	—
8.2.3	Synch manager state machine (SYMSM)	YES	—
8.2.4	Resilient Mailbox State Machine (RMSM)	YES	—

Clause	Header	Presence	Constraints
8.2.5	SII State Machine (SIISM)	YES	—
8.2.6	MII State Machine (MIISM)	YES	—
8.2.7	DC State Machine (DCSM)	YES	—

13.3.2.2 EtherCAT Master

The data-link layer is described in IEC 61158-3-12 and IEC 61158-4-12. Table 194 specifies the use of the services, specified in IEC 61158-3-12, included in this profile. Table 195 specifies the use of the protocol, specified in IEC 61158-3-12, included in this profile. The selection of services used is up to the master. The Auto Increment Read and Write Services are mandatory.

Table 194 – CP 12/2: DLL service selection

Clause	Header	Presence	Constraints
4	Data-link layer services and concepts	—	—
4.1	Operating principle	YES	—
4.2	Topology	YES	—
4.3	Data-link layer overview	YES	—
4.4	Error detection overview	YES	—
4.5	Parameter and process data handling introduction	YES	—
4.6	Node reference model	YES	—
4.7	Operation overview	Partial	Direct mode mandatory
4.8	Addressing	YES	—
4.9	Slave classification	NO	—
4.10	Structure of the communication layer in the slave	YES	—
5	Communication services	—	—
5.1	Overview	YES	—
5.2	Read services	Partial	Requestor Services (.req/.cnf)
5.3	Write services	Partial	Requestor Services (.req/.cnf)
5.4	Combined read/write services	Partial	Requestor Services (.req/.cnf)
5.5	Network services	NO	—
5.6	Mailbox	NO	—
6	Local interactions	—	—
6.1	Read local	YES	—
6.2	Write local	YES	—

Table 195 – CP 12/2: DLL protocol selection

Clause	Header	Presence	Constraints
4	Overview of the DL-protocol	—	—
4.1	Operating principle	YES	—
4.2	Topology	YES	—
4.3	Frame processing principles	YES	—
4.4	Data-link layer overview	YES	—
4.5	Error detection overview	YES	—
4.6	Node reference model	YES	—
4.7	Operation overview	Partial	Direct mode mandatory
5	Frame Sructure	—	—
5.1	Frame coding principles	YES	—
5.2	Data types and encoding rules	Partial	Types needed for application and unsigned integer types
5.3	DL PDU structure	YES	—
5.4	Type 12 DLPDU structure	YES	—
5.5	Network variable structure	NO	—
5.6	Type 12 mailbox structure	NO	—
6	Attributes	—	—
6.1	Management	YES	—
6.2	Statistics	YES	—
6.3	Watchdogs	YES	—
6.4	Slave information interface	YES	—
6.5	Media independent interface (MII)	YES	—
6.6	Fieldbus memory management unit (FMMU)	YES	—
6.7	Sync manager	YES	—
6.8	Distributed Clock	Optional	If time based synchronization is supported
7	DL-user memory	—	—
7.1	Overview	YES	—
7.2	Mailbox access type	YES	—
7.3	Buffered access type	YES	—
8	Type 12:FDL Protocol state machines	—	—
8.1	Overview of slave DL state machines	NO	—
8.2	State machine description	—	—
8.2.1	Port state machine (PSM)	NO	—
8.2.2	PDU handler state machine (DHSM)	NO	—
8.2.3	Synch manager state machine (SYMSM)	NO	—
8.2.4	Resilient Mailbox State Machine (RMSM)	NO	—
8.2.5	SII State Machine (SIISM)	NO	—
8.2.6	MII State Machine (MIISM)	NO	—
8.2.7	DC State Machine (DCSM)	NO	—

13.3.3 Application layer

13.3.3.1 EtherCAT Slave

The application layer is described in IEC 61158-5-12 and IEC 61158-6-12. Table 196 specifies the use of the services, specified in IEC 61158-5-12, included in this profile. Table 197 specifies the use of the protocol, specified in IEC 61158-6-12, included in this profile.

Table 196 – CP 12/2: AL service selection

Clause	Header	Presence	Constraints
4	Concepts	—	—
4.1	Common concepts	YES	—
4.2	Type specific concepts	—	—
4.2.1	Operating principle	YES	—
4.2.2	Communication model overview	YES	—
4.2.3	Application layer element description	YES	—
4.2.4	Slave reference model	YES	—
4.2.5	Master reference model	NO	—
5	Data Type ASE	YES	—
6	Communication model specification		—
6.1	ASEs	—	—
6.1.1	Process data ASE	YES	—
6.1.2	SII ASE	YES	—
6.1.3	Isochronous ASE	Optional	—
6.1.4	CoE ASE	Optional	—
6.1.5	EoE ASE	Optional	—
6.1.6	FoE ASE	Optional	—
6.1.7	MBX ASE	Optional	—
6.2	AR	YES	—

Table 197 – CP 12/2: AL protocol selection

Clause	Header	Presence	Constraints
4	Application Layer protocol specification	—	—
4.1	Operating principle	YES	—
4.2	Node reference model	YES	—
5	FAL syntax description	—	—
5.1	Coding principles	YES	—
5.2	Data types and encoding rules	YES	—
5.3	AR coding	YES	Bootstrap optional
5.4	SII coding	YES	—
5.5	Isochronous PDI coding	Optional	—
5.6	CoE coding	Optional	—
5.7	EoE coding	Optional	—
5.8	FoE coding	Optional	—
6	FAL protocol state machine	—	—

Clause	Header	Presence	Constraints
6.1	Overall structure	YES	—
6.2	AP-Context state machine	YES	—
6.3	FAL service protocol machine (FSPM)	YES	—
6.4	Application Relationship Protocol Machines (ARPMs)	—	—
6.4.1	AL state machine	YES	Bootstrap optional
6.4.2	Mailbox handler state machine	YES	—
6.4.3	CoE state machine	Optional	—
6.4.4	EoE state machine	Optional	—
6.4.5	FoE state machine	Optional	—
6.5	DLL mapping protocol machine (DMPM)	YES	—

13.3.3.2   EtherCAT Master

The application layer is described in IEC 61158-5-12 and IEC 61158-6-12. Table 198 specifies the use of the services, specified in IEC 61158-5-12, included in this profile. Table 199 specifies the use of the protocol, specified in IEC 61158-6-12, included in this profile.

Table 198 – CP 12/2: AL service selection

Clause	Header	Presence	Constraints
4	Concepts	—	—
4.1	Common concepts	YES	—
4.2	Type specific concepts	—	—
4.2.1	Operating principle	YES	—
4.2.2	Communication model overview	YES	—
4.2.3	Application layer element description	YES	—
4.2.4	Slave reference model	NO	—
4.2.5	Master reference model	YES	—
5	Data Type ASE	YES	—
6	Communication model specification	—	—
6.1	ASEs	—	—
6.1.1	Process Data ASE	YES	—
6.1.2	SII ASE	YES	—
6.1.3	Isochronous ASE	Optional	—
6.1.4	CoE ASE	YES	—
6.1.5	EoE ASE	Optional	—
6.1.6	FoE ASE	Optional	—
6.1.7	MBX ASE	Optional	—
6.2	AR	YES	—

Table 199 – CP 12/2: AL protocol selection

Clause	Header	Presence	Constraints
4	Application Layer protocol specification	—	—
4.1	Operating principle	YES	—
4.2	Node reference Model	YES	—
5	FAL syntax description	—	—
5.1	Coding principles	YES	—
5.2	Data types and encoding rules	YES	—
5.3	AR coding	YES	Bootstrap optional
5.4	SII coding	YES	—
5.5	Isochronous PDI coding	Optional	—
5.6	CoE coding	YES	—
5.7	EoE coding	Optional	—
5.8	FoE coding	Optional	—
6	FAL protocol state machine	—	—
6.1	Overall structure	YES	—
6.2	AP-Context state machine	YES	—
6.3	FAL service protocol machine (FSPM)	YES	—
6.4	Application Relationship Protocol Machines (ARPMs)	—	—
6.4.1	AL state machine	NO	—
6.4.2	Mailbox handler state machine	NO	—
6.4.3	CoE state machine	YES	—
6.4.4	EoE state machine	Optional	—
6.4.5	FoE state machine	Optional	—
6.5	DLL mapping protocol machine (DMPM)	YES	—

13.3.4 Performance indicator selection

13.3.4.1 Performance indicator overview

The performance indicator overview of 13.2.4.1 applies.

Table 200 gives an overview of the performance indicator usage.

Table 200 – CP 12/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	—
Number of switches between end-stations	NO	Slave Device includes switch functionality
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	YES	—
Non-time-based synchronization accuracy	YES	—
Redundancy recovery time	Optional	—

13.3.4.2 Performance indicator dependencies

Table 201 specifies the dependencies of the performance indicators (row) from the performance indicators (column).

Table 201 – CP 12/2: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchron. accuracy	Non-time-based synchronization accuracy	Redundancy recovery time
Delivery time		YES 13.2.4.4	NO	YES 13.2.4.5	NO	NO	NO	YES 13.2.4.6
Number of end-stations	NO		NO	NO	NO	YES 13.3.4.4	YES 13.2.4.7	NO
Basic network topology	NO	NO		NO	NO	NO	NO	YES 13.2.4.8
Throughput RTE	NO	NO	NO		YES 13.2.4.9	NO	NO	NO
Non-RTE bandwidth	NO	NO	NO	YES 13.2.4.9		NO	NO	NO
Time synchronization accuracy	NO	YES 13.3.4.4	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	YES 13.2.4.7	NO	NO	NO	NO		NO
Redundancy recovery time	NO	NO	YES 13.2.4.8	NO	NO	NO	NO	

13.3.4.3 Calculation of delivery time

The delivery time is calculated according to Formula (60).

13.3.4.4 Relation between number of end-stations and time synchronization accuracy

Number of end-stations influences the time synchronization accuracy and vice versa.

13.3.4.5 Consistent set of performance indicators for large automation systems

Table 202 gives an outline of a consistent set of performance indicators for a large automation system with a cycle time of 200 µs and 500 m network extension.

Table 202 – CP 12/2: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery time	< 519 µs	No failure
Number of end-stations	650	—
Number of switches between end-stations	NA	—
Throughput RTE	10 500 000 octets/s	—
Non-RTE bandwidth	55,9 %	—
Time synchronization accuracy	<< 1 µs	Depends on slave device hardware implementation, typically less than 200 ns
Non-time-based synchronization accuracy	10 µs	—
Redundancy recovery time	200 µs	—

14 Communication Profile Family 13 (Ethernet POWERLINK[12]) – RTE communication profiles

14.1 General overview

Communication Profile Family 13 (CPF 13) defines a profile using Type 13 of the IEC 61158 series, which correspond to the communication system commonly known as Ethernet POWERLINK.

– Profile 13/1

This profile contains AL, and DLL services and protocol definitions from IEC 61158-3-13, IEC 61158-4-13, IEC 61158-5-13 and IEC 61158-6-13.

Table 203 shows the overview of Ethernet POWERLINK profile set.

Table 203 – CPF 13: Overview of profile sets

Layer	Profile 13/1
Application	IEC 61158-5-13, IEC 61158-6-13
Data-link	IEC 61158-3-13, IEC 61158-4-13
Physical	ISO/IEC/IEEE 8802-3

_____

12 Ethernet POWERLINK is a trade name of Bernecker&Rainer Industrieelektronik Ges.m.b.H., control of trade name use is given to the non profit organization EPSG. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

14.2 Profile 13/1

14.2.1 Physical layer

The physical layer shall be according to ISO/IEC/IEEE 8802-3.

14.2.2 Data-link layer

14.2.2.1 DLL services selection

The data-link layer services are defined in IEC 61158-3-13. Table 204 shows the subclauses included in this profile.

Table 204 – CP 13/1: DLL service selection

Clause	Header	Presence	Constraints
Whole document	Data link service specification (Type 13)	YES	—

14.2.2.2 DLL protocol selection

The data-link layer protocols are defined in IEC 61158-4-13. Table 205 shows the subclauses included in this profile.

Table 205 – CP 13/1: DLL protocol selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 13)	YES	—

14.2.3 Application layer

14.2.3.1 AL service selection

The application layer services are defined in IEC 61158-5-13. Table 206 shows the subclauses included in this profile.

Table 206 – CP 13/1: AL service selection

Clause	Header	Presence	Constraints
Whole document	Application layer service specification (Type 13)	YES	—

14.2.3.2 AL protocol selection

The application layer protocols are defined in IEC 61158-6-13. Table 207 shows the subclauses included in this profile.

Table 207 – CP 13/1: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Application layer protocol specification (Type 13)	YES	—

14.2.4   Performance indicator selection

14.2.4.1   Performance indicator overview

Table 208 shows the performance indicators overview of CP 13/1.

Table 208 – CP 13/1: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	Star and linear topology
Number of switches between end-stations	YES	For highest performance use repeaters instead of switches
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	YES	—
Non time-based synchronization accuracy	YES	—
Redundancy recovery time	YES	—

14.2.4.2   Performance indicator dependencies

14.2.4.2.1   Performance indicator dependency matrix

Table 209 shows the dependencies between performance indicators for CP 13/1.

Table 209 – CP 13/1: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy	Non-time-based synchronization accuracy	Redundancy recovery time
Delivery time		YES 14.2.4.2.5	YES 14.2.4.2.6	YES 14.2.4.2.8	NO	NO	NO	NO
Number of end-stations	YES 14.2.4.2.3		NO	NO	NO	NO	NO	NO
Basic network topology	YES 14.2.4.2.4	NO		NO	NO	YES 14.2.4.2.11	YES 14.2.4.2.12	YES 14.2.4.2.13
Throughput RTE	NO	NO	NO		YES 14.2.4.2.10	NO	NO	NO
Non-RTE bandwidth	NO	NO	YES 14.2.4.2.7	YES 14.2.4.2.9		NO	NO	NO
Time synchronization accuracy	NO	NO	NO	NO	NO		NO	NO
Non-time-based synchronization accuracy	NO	NO	NO	NO	NO	NO		NO
Redundancy recovery time	NO	NO	NO	NO	NO	NO	NO	

14.2.4.2.2   Delivery time

The delivery time is dependent on the communication cycle time and properties of the specific end-station. Data which is produced is transmitted in the following communication cycle and processed by the receiving node at the beginning of the third communication cycle.

The delivery time for communication between two RTE end-stations can be calculated by Formula (61).

$$T_D = T_{PS} + T_C + T_{PR} \tag{61}$$

where

T_D is the delivery time;

T_C is the communication cycle time, see Formula (62);

T_{PR} is the processing time in the receiving end-station.

T_{PS} is the processing time in the sending end-station.

The communication cycle time T_C can be calculated by Formula (62).

$$T_C = T_S + T_A + \sum_{i=1}^{N}\left(T_{FT,i} + T_{RD,i} + T_{SD,i}\right) \tag{62}$$

where

T_C	is the communication cycle time;
T_S	is the communication cycle start delay;
N	is the number of RTE end-stations processed in one communication cycle;
$T_{FT,i}$	is the RTE frames transmission time for RTE end-station i (depends on the amount of APDU data for this node);
$T_{RD,i}$	is the response delay of the RTE end-station i;
$T_{SD,i}$	is the sum of all delays of infrastructure components (switches, repeaters, cabling) for the RTE end-station i;
T_A	is the time reserved for non-RTE data within one communication cycle.

The delivery time with one lost frame for communication between two RTE end-stations can be calculated by Formula (63).

$$T_D = T_{PS} + 2 \times T_C + T_{PR} \tag{63}$$

where

T_D	is the delivery time;
T_C	is the communication cycle time, see Formula (62);
T_{PR}	is the processing time in the receiving end-station.
T_{PS}	is the processing time in the sending end-station.

14.2.4.2.3 Delivery time dependency on number of end-stations

Typically the amount of APDU data increases with the number of end-stations. Moreover additional delays are introduced with every extra node (by the node itself and additional network infrastructure components if necessary). Both parameters are considered in Formula (62) and therefore influence the delivery time as calculated by Formula (61).

14.2.4.2.4 Delivery time dependency on basic network topology

Basic network topology influences signal propagation delay between two RTE end-stations which limits the communication cycle time and consequently the delivery time.

14.2.4.2.5 Number of end-stations dependency on delivery time

As shown in Formula (61) the delivery time is given by the communication cycle time. As every node occupies a certain amount of time within the communication cycle there is a limit on the number of nodes if a certain delivery time is to be accomplished.

14.2.4.2.6 Basic network topology dependency on delivery time

A given delivery time limits the amount of tolerable signal propagation delays which are introduced by a given network topology.

14.2.4.2.7 Basic network topology dependency on non-RTE bandwidth

Non-RTE bandwidth is provided by a fixed time slice of the communication cycle and therefore dependent on delivery time. From this it follows that basic network topology is also dependent on non-RTE bandwidth.

14.2.4.2.8   Throughput RTE dependency on delivery time

A certain delivery time limits the amount of APDU which can be transmitted within one communication cycle. Throughput RTE is a function of APDU size and communication cycle time and therefore dependent on delivery time.

14.2.4.2.9   Throughput RTE dependency on non-RTE bandwidth

Non-RTE bandwidth is provided by a fixed time slice of one communication cycle. This time slice can not be used for real-time data and therefore limits throughput RTE.

14.2.4.2.10   Non-RTE bandwidth dependency on Throughput RTE

Non-RTE bandwidth is provided by a fixed time slice of one communication cycle. More RTE data sent within one communication cycle reduces the time available for non-RTE communication.

Non-RTE bandwidth is derived from the communication cycle time and network maximum transmission unit (MTU) size as calculated by Formula (64). Total link bandwidth corresponds to full link rate according ISO/IEC/IEEE 8802-3 (e.g. 100 Mbit/s).

$$B_{NRTE} = \frac{M}{125\,000 \times T_C} \qquad (64)$$

where

B_{NRTE} is the non-RTE bandwidth;

M is the network MTU in octets;

T_C is the communication cycle time.

14.2.4.2.11   Time synchronization accuracy dependency on basic network topology

On the transmission path between two communicating RTE end-stations several switches (or other network infrastructure components) can be traversed, each causing jitter of the receive time, thus influencing the time synchronization accuracy.

14.2.4.2.12   Non-time-based synchronization accuracy dependency on basic network topology

Subclause 14.2.4.2.8 applies.

14.2.4.2.13   Redundancy recovery time dependency on basic network topology

Basic network topology determines duration and method of failure detection and recovery.

14.2.4.3   Consistent set of performance indicators

Table 210 shows one consistent set of performance indicators for CP 13/1 using a network bandwidth of 100 Mbit/s. The values in Table 210 represent a practical example of a small sized system for machine automation. This system operates at a communication cycle time of 150 μs and is connected by a realistic network infrastructure using star topology. The numerical calculations are based on worst case performance values of devices widely installed in the field for this type of automation system.

Table 210 – CP 13/1: Consistent set of PIs small size automation system

Performance indicator	Value	Constraints
Delivery Time	350 μs	Processing time is 100 μs at sender and receiver, no failure
Number of end-stations	4	—
Number of switches between end-stations	0	1 Repeater used instead of switches
Throughput RTE	1,9 Moctets/s	—
Non-RTE bandwidth	19,6 %	Network MTU is 369 octets
Time synchronization accuracy	< 1 s	Implementation dependent
Non time-based synchronization accuracy	< 200 ns	Depends on location of node within network topology
Redundancy recovery time	150 μs	—

Table 211 shows one consistent set of performance indicators for CP 13/1 using a network bandwidth of 100 Mbit/s. The values in Table 211 represent a practical example of a medium sized system for machine automation. This system operates at a communication cycle time of 500 μs and is connected by a realistic network infrastructure using combined star and linear topology. The numerical calculations are based on worst case performance values of devices widely installed in the field for this type of automation system.

Table 211 – CP 13/1: Consistent set of PIs medium size automation system

Performance indicator	Value	Constraints
Delivery Time	700 μs	Processing time is 100 μs at sender and receiver, no failure
Number of end-stations	20	—
Number of switches between end-stations	0	7 Repeaters used instead of switches
Throughput RTE	2,5 Moctets/s	—
Non-RTE bandwidth	11,5 %	Network MTU is 720 octets
Time synchronization accuracy	< 1 s	Implementation dependent
Non time-based synchronization accuracy	< 440 ns	Depends on location of node within network topology
Redundancy recovery time	500 μs	—

Table 212 shows one consistent set of performance indicators for CP 13/1 using a network bandwidth of 100 Mbit/s. The values in Table 212 represent a practical example of a large sized system for machine or process automation. This system operates at a communication cycle time of 2 700 μs and is connected by network infrastructure using star topology. The numerical calculations are based on worst case performance values of devices widely installed in the field for this type of automation system.

Table 212 – CP 13/1: Consistent set of PIs large size automation system

Performance indicator	Value	Constraints
Delivery Time	2 900 μs	Processing time is 100 μs at sender and receiver, no failure
Number of end-stations	150	—
Number of switches between end-stations	0	3 Repeaters used instead of switches
Throughput RTE	4 Moctets/s	—
Non-RTE bandwidth	4,4 %	Network MTU is 1 500 octets
Time synchronization accuracy	< 1 s	Implementation dependent
Non time-based synchronization accuracy	< 280 ns	Depends on location of node within network topology
Redundancy recovery time	2 700 μs	—

15 Communication Profile Family 14 (EPA[13])- RTE communication profiles

15.1 General overview

Communication Profile Family 14 (CPF 14) defines communication profiles based on IEC 61158-3-14, IEC 61158-4-14, IEC 61158-5-14 and IEC 61158-6-14, which correspond to parts of the communication systems commonly known as real-time EPA (Ethernet for Plant Automation).

– Profile 14/1

This profile contains a selection of AL, DLL and PHL services and protocol definitions from IEC 61158-3-14, IEC 61158-4-14, IEC 61158-5-14 and IEC 61158-6-14. This profile provides real time communication using IEEE 802 series and IETF communication protocols with accurate time synchronization based on IEC 61588.

This profile support communications between master devices and bridges.

– Profile 14/2

This profile provides ISO/IEC/IEEE 8802-3-based real time communication with deterministic communications defined in IEC 61158-3-14 and IEC 61158-4-14.

This profile supports communication between field devices and bridges.

– Profile 14/3

This profile contains a selection of AL, DLL and PHL services and protocol definitions from IEC 61158-3-14, IEC 61158-4-14, IEC 61158-5-14 and IEC 61158-6-14. This profile provides real time communication using IEEE 802 series. IETF communication protocols can be used if necessary. Accurate time synchronization based on IEC 61588 should be used.

– Profile 14/4

This profile provides ISO/IEC/IEEE 8802-3-based real time communication with deterministic communications defined in IEC 61158-3-14 and IEC 61158-4-14. This profile contains a selection of AL services and protocol definitions from IEC 61158-5-14 and IEC 61158-6-14.

This profile supports communication between master devices and field devices.

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13 EPA™ is a trade name of SUPCON Group Co. Ltd. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

15.2 CPF 14 (EPA) communication concept

15.2.1 General

The EPA system is a distributed system which uses the Ethernet network defined by ISO/IEC/IEEE 8802-3, IEEE 802 series and IETF protocols to connect field devices and small systems, and to control/monitor equipment in the industrial field. EPA devices work together to provide I/O and control for automated processes and operations.

The EPA system architecture provides a framework for describing these systems as the collection of physical devices interconnected by an EPA network. The objective of 15.2 is to identify the components of the system, describe their relationships and interactions, and define how they are configured.

15.2.2 Network Topology

Figure 12 shows an example of the EPA network topology with two subnets, process monitor layer subnet (L2-subnet) and field device layer subnet (L1-subnet).

The following describes the characteristics of EPA topology:

- a L1-subnet is used to connect field devices (such as transmitters, actuators and analytical instruments, etc.) mounted in field environment;
- a L1-subnet can be separated into more than one micro-segments, where the time-sharing controlling mechanism is used to meet the demands of deterministic communication;
- a L2-subnet is used to connect the devices of control center and HMI devices and one or more micro-segments. In L2-subnet, regular communication schedule based on CSMA/CD defined in ISO/IEC/IEEE 8802-3 is applied when deterministic communication is not necessary;
- devices on both L1-subnets and L2-subnets may be interconnected with standard switches or hubs;
- an EPA device may function as a bridge, which interconnects a L1-subnet micro-segment to a L2-subnet. This EPA bridge performs message filtering and forwarding between L1-subnet and L2-subnet.
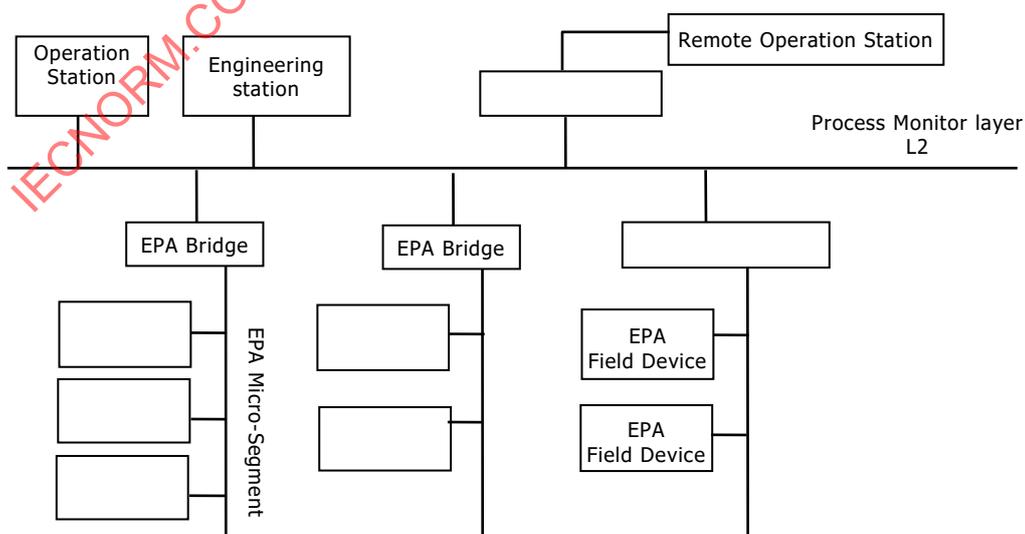
Figure 12 – EPA system network topology example

A micro-segment is a control area, where EPA devices communicate with each other to implement specific measuring and control functions. That is, the devices which need to communicate with each other shall be interconnected in the same L1 micro-segment.

Those devices consisting of a control loop or function block application process, such as transmitters, actuators and controllers which need to communicate with each other, shall be interconnected in the same micro-segment.

15.2.3 EPA devices

15.2.3.1 EPA master device

An EPA master device is connected to a L2-subnet directly. An EPA master device has an EPA communication interface but may have no control function block or function block application. An EPA master device may commonly be a configuration device, a monitoring device or a HMI station.

An EPA master device has a unique IP address in a system.

15.2.3.2 EPA field device

An EPA field device is installed in the industrial field environment. EPA field devices must have EPA a communication entity and at least include one function block instance.

An EPA field Device has a unique IP address in a system.

15.2.3.3 EPA bridge

An EPA bridge is an optional device that interconnects one L1-subnet micro-segment to a L2-subnet. An EPA bridge has at least has two communication interfaces, connecting one L1-subnet micro-segment and one L2-subnet respectively.

An EPA bridge can be configured to provide the following functions:

- communication isolation

  When the traffic occurs between two devices connected in one micro-segment, the EPA bridge shall provide limit it within the segment. Here, the traffic includes broadcast, multicast and peer to peer communication flows.

- message forwarding and filtering

  An EPA bridge transmit shall forward and filter the messages between one L1-subnet micro-segment and another L1-segment or L2-subnet. That is, when forwarding a message, the EPA bridge shall examine whether it should be forwarded according to configured criteria.

NOTE   As an optional device, an EPA bridge is not necessary if the number of nodes in a system is not too large.

15.2.3.4 EPA agent

An EPA agent is an optional device used to interconnect an EPA network and other different networsk. It shall provide the function of security control for the remote access.

15.3 Profile 14/1

15.3.1 Physical layer

The physical layer of the EPA profile is according to ISO/IEC/IEEE 8802-3. for wired connection, ISO/IEC 8802-11 and IEEE 802.15.1 for wireless connection

15.3.2 Data-link layer

The data-link layer shall be according to ISO/IEC/IEEE 8802-3, IEEE 802-1D, ISO/IEC 8802-11 and IEEE 802.15.1.

15.3.3 Network Layer

Internet standard RFC 791 (IP), RFC 826 (ARP), RFC 792 (ICMP) and their amendments and successors shall be used.

15.3.4 Transport Layer

Internet standard RFC 768 (UDP), RFC 793 (TCP) and their amendments and successors may be used. But for real-time applications, RFC 768 shall be used for field devices, bridges and master devices.

15.3.5 Application layer

15.3.5.1 AL service selection

The application layer services for profile 14/1 are defined in IEC 61158-5-14. Table 213 specifies the clauses included in this profile.

Table 213 – CP 14/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations	Partial	Used when applicable
4	Concepts	Partial	Used when applicable
5	Data type ASE	YES	—
6	Communication model specification	YES	—

15.3.5.2 AL protocol selection

The application layer protocols for profile 14/1 are defined IEC 61158-6-14. Table 214 specifies the clauses included in this profile.

Table 214 – CP 14/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Abstract syntax	YES	—
4.1	Fixed format PDU description	YES	—
4.2	Object definitions in FAL management ASE	YES	—
4.3	Definition of objects used in Type 14 application access entity	YES	—
5	Transfer syntax	YES	—
5.1	Encoding of basic data types	YES	—
5.2	Encoding of Type 14 APDU header	YES	—
5.3	Encoding of FAL management entity service parameters	YES	—
5.4	Encoding of AAE Services	YES	—
6	Structure of FAL protocol state machines	YES	—
7	AP-Context state machine	YES	—
8	FAL management state machines	YES	—
9	Application access entity protocol machine	YES	—
10	Application relationship state machine	YES	—
11	DLL mapping protocol machine	YES	—

15.3.6 Performance indicator selection

15.3.6.1 Performance indicator overview

Table 215 provides an overview of CP 14/1 performance indicators.

Table 215 – CP 14/1: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	—
Number of switches between end-stations	YES	—
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	YES	—
Non-time-based synchronization accuracy	NO	—
Redundancy recovery time	YES	—

15.3.6.2 Performance indicator dependencies

Table 216 specifies PI dependencies included in this profile.

Table 216 – CP 14/1: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accurancy	Redundancy recovery time
Delivery time		YES	NO	YES	YES	NO	NO	NO
Number of end-stations	YES		NO	NO	NO	NO	NO	NO
Basic network topology	YES	NO		NO	NO	NO	YES	YES
Number of switches between end-stations	YES	NO	NO		NO	NO	YES	YES
Throughput RTE	NO	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	NO		YES	NO
Time synchronization accuracy	NO	YES	NO	YES	NO	NO		NO
Redundancy recovery time	YES	NO	YES	YES	NO	NO	NO	

15.3.6.2.1 Delivery Time

The performance indicator delivery time can be calculated by Formula (65).

$$DT = TStack\_S + TQueue\_S + TEthernet\_S + TTrf\_S \times Ndata + \qquad (65)$$
$$TCable \times LCable + TSwitch \times NSwitch + TStack\_R$$

where

DT	is the delivery time;
$TStack\_S$	is the sender stack processing time;
$TQueue\_S$	is the sender queuing delay;
$TEthernet\_S$	is the sender traversal time through MAC and Phy based on ISO/IEC/IEEE 8802-3;
$TTrf\_S$	is the transfer time for an octet;
$Ndata$	is the length in octets of complete Ethernet frame;
$TCable$	is the cable delay;
$LCable$	is the cable length;
$TSwitch$	is the Switch delay;
$NSwitch$	is the Number of switches between end-stations;
$TStack\_R$	is the receiver stack processing time including Phy and MAC.

As shown in Formula (65):

- the number of end-stations influences DT with queue delay;

- the number of switches between end-stations influences DT. DT will be longer when the number of switches between end-stations increases;

- the throughput RTE influences DT. That is, DT will be longer due to queue delay when Throughput RTE increases.

15.3.6.2.2   Number of end-stations

If the delivery time is set to the bounded delivery time, then the maximum number of end-stations is restricted.

15.3.6.2.3   Basic network topology

The basic network topology is designed in linear, star, ring or daisy-chain according to the delivery time in application. If the delivery time is preset to the boundary delivery time, the basic network topology shall be set to a hierarchical star.

If the time synchronization accuracy is set to the minimum value, the basic network topology shall be set to a hierarchical star.

If redundancy recovery time is allowed to use rapid spanning tree algorithm according to IEEE 802.1D, then the basic network topology can be designed in linear, star, ring or daisy-chain.

15.3.6.2.4   Number of switches between end-stations

The number of switches between end-stations shall be designed to a minimum value so that delivery time, time synchronization accuracy and redundancy recovery accuracy meet the application demands.

15.3.6.2.5   Relation between Throughput RTE and Non-RTE bandwidth

The relation between Throughput RTE and Non-RTE bandwidth is specified in Formula (66).

$$NRTE\_BW = ((RateofEthernet − ThroughputRTE × 8) / RateofEthernet) × 100 \% \tag{66}$$

where

$NRTE\_BW$ is the non-RTE bandwidth, in %;

$RateofEthernet$ is the Ethernet data rate in Mbit/s;

$ThroughputRTE$ is the RTE throughput in octets/s.

Throughput RTE can be calculated by Formula (67).

$$ThroughputRTE = (∑ (RTEData + TSData + RMData)) / s \tag{67}$$

where

$ThroughputRTE$ is the RTE throughput in octets/s;

$RTEData$ is the real-time data in octets;

$TSData$ is the time synchronization data in octets;

$RMData$ is the redundancy management data in octets.

15.3.6.2.6   Time synchronization accuracy

Time synchronization accuracy depends on synchronization cycle and switch delay. The synchronization cycle depends on the number of end-stations and the switch delay depends on the number of switches between end-stations.

15.3.6.2.7 Redundancy recovery time

The time to detect the failure is dependent from the number of switches between end-stations.

15.3.6.3 Consistent set of performance indicators

Table 217 specifies consistent set of PI included in this profile.

Table 217 – CP 14/1: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery time	5 ms	Without failure
	10 ms	1 frame lost
Number of end-stations	32	Star topology with switches
Number of switches between end-stations	4	—
Throughput RTE	1 536 000 octets/s	—
Non-RTE bandwidth	85 %	100 Mbit/s Ethernet
Time synchronization accuracy	< 10 μs	—
Redundancy recovery time	< 300 ms	—

15.4 Profile 14/2

15.4.1 Physical layer

The physical layer of the EPA profile is according to ISO/IEC/IEEE 8802-3. EPA devices may use a data rate of 10 Mbit/s, 100 Mbit/s and higher. The topology shall be linear, star, ring or the combination of the above.

15.4.2 Data-link layer

The data-link layer shall be according to ISO/IEC/IEEE 8802-3, IEEE 802-1D.

In addition, EPA Communication Scheduling Management Entity (ECSME) is defined on ISO/IEC/IEEE 8802-3 data-link services are defined in IEC 61158-3-14, and data-link protocol to manage the deterministic communication in IEC 61158-4-14.

Table 218 defines the DLL service selection from IEC 61158-3-14 for profile 14/2.

Table 218 – CP 14/2: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	DL Service and concept	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DLL	YES	—
5	DL-management services	YES	—
5.1	Overview	Partial	Used when applicable
5.2	Non-periodic data annunciation	YES	—
5.3	EndofNonPeriodicDataSendingAnnunciation service	YES	—
5.4	DL-management for FRT applications	—	—

Table 219 defines the DLL protocol selections from IEC 61158-4-14 for CP14/2.

Table 219 – CP 14/2: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols and abbreviations	Partial	Used when applicable
4	Overview of the DL-protocol	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DL	YES	—
4.3	Structure of deterministic communication scheduling	YES	—
5	Procedure of deterministic communication scheduling	–	—
5.1	Overview	YES	—
5.2	State transitions	YES	—
5.3	State table	YES	—
5.4	Function descriptions	–	—
6	Structure and encoding of ECSME PDU	YES	—

15.4.3 Network Layer

Internet standard RFC 791 (IP), RFC 826 (ARP), RFC 792 (ICMP) and their amendments and successors shall be used.

15.4.4 Transport Layer

Internet standard RFC 768 (UDP), RFC 793 (TCP) and their amendments and successors may be used. But for real-time applications, RFC 768 shall be used for field devices, bridges and master devices.

15.4.5　Application layer

15.4.5.1　AL service selection

The application layer services for profile 14/2 are defined in IEC 61158-5-14. Table 220 specifies the clauses included in this profile.

Table 220 – CP 14/2: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Concepts	Partial	Used when applicable
5	Data type ASE	YES	—
6	Communication model specification	YES	—

15.4.5.2　AL protocol selection

The application layer protocol for profile 14/2 is defined in IEC 61158-6-14. Table 221 specifies the clauses included in this profile.

Table 221 – CP 14/2: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Abstract syntax	YES	—
4.1	Fixed format PDU description	YES	—
4.2	Object definitions in FAL management ASE	YES	—
4.3	Definition of objects used in Type 14 application access entity	YES	—
5	Transfer syntax	YES	—
5.1	Encoding of basic data types	YES	—
5.2	Encoding of Type 14 APDU header	YES	—
5.3	Encoding of FAL management entity service parameters	YES	—
5.4	Encoding of AAE Services	YES	—
6	Structure of FAL protocol state machines	YES	—
7	AP-Context state machine	YES	—
8	FAL management state machines	YES	—
9	Application access entity protocol machine	YES	—
10	Application relationship state machine	YES	—
11	DLL mapping protocol machine	YES	—

15.4.6 Performance indicator selection

15.4.6.1 Performance indicator overview

Table 222 provides an overview of CP 14/2 performance indicators.

Table 222 – CP 14/2: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	—
Number of switches between end-stations	YES	—
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	YES	—
Non-time-based synchronization accuracy	NO	—
Redundancy recovery time	YES	—

15.4.6.2 Performance indicator dependencies

Table 223 specifies the performance indacator dependencies for CP 14/2.

Table 223 – CP 14/2: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accurancy	Redundancy recovery time
Delivery time		YES	NO	YES	YES	NO	NO	NO
Number of end-stations	YES		NO	NO	NO	NO	NO	NO
Basic network topology	YES	NO		NO	NO	NO	YES	YES
Number of switches between end-stations	YES	NO	NO		NO	NO	YES	YES
Throughput RTE	NO	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	NO		YES	NO
Time synchronization accuracy	NO	YES	NO	YES	NO	NO		NO
Redundancy recovery time	YES	NO	YES	YES	NO	NO	NO	

15.4.6.2.1 Delivery Time

The performance indicator delivery time can be calculated by Formula (68).

$$DT = TStack\_S + TQueue\_S + TEthernet\_S + TTrf\_S \times Ndata + TCable \times LCable \quad (68)$$
$$+ TSwitch \times NSwitch + TStack\_R$$

where

DT	is the delivery time;
$TStack\_S$	is the sender stack processing time;
$TQueue\_S$	is the sender queuing delay, the max queue delay is equal to cycle time, the minimum queue delay is 0;
$TEthernet\_S$	is the sender traversal time through MAC and Phy based on ISO/IEC/IEEE 8802-3;
$TTrf\_S$	is the transfer time for an octet;
$Ndata$	is the length in octets of complete Ethernet frame;
$TCable$	is the cable delay;
$LCable$	is the cable length;
$TSwitch$	is the Switch delay;
$NSwitch$	is the Number of switches between end-stations;
$TStack\_R$	is the receiver stack processing time including Phy and MAC.

As shown in Formula (68),

- the number of end-stations influences DT with queue delay;

- the number of switches between end-stations influences DT. DT will be enlarged when the number of switches between end-stations increases;

- the throughput RTE influences DT. That is, DT will be enlarged due to queue delay when Throughput RTE increases. The max queue delay is equal to cycle time, and the minimum queue delay is 0.

15.4.6.2.2   Number of end-stations

If the delivery time is set to the bounded delivery time, then the maximum number of end-stations is restricted.

15.4.6.2.3   Basic network topology

The basic network topology is designed in linear, star, ring or daisy-chain according to the delivery time in application. If the delivery time is preset to the boundary delivery time, the basic network topology shall be set to a hierarchical star.

If the time synchronization accuracy is set to the minimum value, the basic network topology shall be set to a hierarchical star.

If redundancy recovery time is allowed to use rapid spanning tree algorithm according to IEEE 802.1D, then the basic network topology can be designed in linear, star, ring or daisy-chain.

15.4.6.2.4   Number of switches between end-stations

The number of switches between end-stations shall be designed to a minimum value so that delivery time, time synchronization accuracy and redundancy recovery accuracy meet the application requirements.

15.4.6.2.5   Throughput RTE and Non-RTE bandwidth

See 15.3.6.2.5.

15.4.6.2.6   Time synchronization accuracy

Time synchronization accuracy depends on synchronization cycle and switch delay. The synchronization cycle depends on the number of end-stations and the switch delay depends on the number of switches between end-stations.

15.4.6.2.7   Redundancy recovery time

The time to detect a failure depends on the number of switches between end-stations.

15.4.6.3   Consistent set of performance indicators

Table 224 specifies a consistent set of PI included in this profile.

Table 224 – CP 14/2: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery Time	100 µs	Without failure
	500 µs	One frame lost
Number of end-stations	64	Star topology with switches connected
Number of switches between end-stations	4	—
Throughput RTE	1 536 000 octets/s	—
Non-RTE bandwidth	85 %	10 Mbit/s Ethernet (full duplex)
Time synchronization accuracy	< 1 µs	—
Redundancy recovery time	< 300 ms	Using IEEE 802.1D

15.5   Profile 14/3

15.5.1   Physical layer

The physical layer of the EPA profile is according to ISO/IEC/IEEE 8802-3. EPA devices may use a data rate of 10 Mbit/s, 100 Mbit/s and higher. The topology shall be linear, star, ring or the combination of the above.

15.5.2   Data-link layer

The data-link layer shall be according to ISO/IEC/IEEE 8802-3, IEEE 802-1D.

In addition, EPA Communication Scheduling Management Entity (ECSME) is defined on ISO/IEC/IEEE 8802-3 data-link services are defined in IEC 61158-3-14, and data-link protocol to manage the deterministic communication in IEC 61158-4-14.

Table 225 defines the DLL service selection from IEC 61158-3-14 for profile 14/3.

Table 225 – CP 14/3: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	DL Service and concept	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DLL	YES	—
5	DL-management services	YES	—
5.1	Overview	Partial	Used when applicable
5.2	Non-periodic data annunciation	YES	—
5.3	EndofNonPeriodicDataSendingAnnunciation service	YES	—
5.4	DL-management for FRT applications	YES	—

Table 226 defines the DLL protocol selections from IEC 61158-4-14 for CP14/3.

Table 226 – CP 14/3: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbolsand abbreviations	Partial	Used when applicable
4	Overview of the DL-protocol	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DL	YES	—
4.3	Structure of deterministic communication scheduling	YES	—
5	Procedure of deterministic communication scheduling	Partial	Used when applicable
5.1	Overview	Partial	Used when applicable
5.2	State transitions	Partial	Used when applicable
5.3	State table	Partial	Used when applicable
5.4	Function descriptions	Partial	Used when applicable
6	Structure and encoding of ECSME PDU	Partial	Used when applicable

15.5.3 Network Layer

Internet standards RFC 791 (IP), RFC 826 (ARP), RFC 792 (ICMP) and their amendments and successors can be used. For FRT applications, RFC 791 can be omitted to enhance real-time performance.

15.5.4 Transport Layer

Internet standards RFC 768 (UDP), RFC 793 (TCP) and their amendments and successors can be used. For FRT applications, RFC 768 can be omitted to enhance real-time performance.

15.5.5 Application layer

15.5.5.1 AL service selection

The application layer services for profile 14/3 are defined in IEC 61158-5-14. Table 227 specifies the clauses included in this profile.

Table 227 – CP 14/3: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Concepts	Partial	Used when applicable
5	Data type ASE	YES	—
6	Communication model specification	YES	—

15.5.5.2 AL protocol selection

The application layer protocols for profile 14/3 are defined in IEC 61158-6-14. Table 228 specifies the clauses included in this profile.

Table 228 – CP 14/3: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Abstract syntax	YES	—
4.1	Fixed format PDU description	YES	—
4.2	Object definitions in FAL management ASE	YES	—
4.3	Definition of objects used in Type 14 application access entity	YES	—
5	Transfer syntax	YES	—
5.1	Encoding of basic data types	YES	—
5.2	Encoding of Type 14 APDU header	YES	—
5.3	Encoding of FAL management entity service parameters	YES	—
5.4	Encoding of AAE Services	YES	—
6	Structure of FAL protocol state machines	YES	—
7	AP-Context state machine	YES	—
8	FAL management state machines	YES	—
9	Application access entity protocol machine	YES	—
10	Application relationship state machine	YES	—
11	DLL mapping protocol machine	YES	—

15.5.6 Performance indicator selection

15.5.6.1 Performance indicator overview

Table 229 provides an overview of CP 14/3 performance indicators.

Table 229 – CP 14/3: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	—
Number of end stations	YES	—
Basic network topology	YES	—
Number of switches between end stations	YES	—
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	YES	—
Non-time-based synchronization accuracy	NO	—
Redundancy recovery time	YES	—

15.5.6.2 Performance indicator dependencies

15.5.6.2.1 Dependency matrix

Table 230 specifies PI dependencies included in this profile.

Table 230 – CP 14/3: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accurancy	Redundency recovery time
Delivery time		YES	NO	YES	YES	NO	NO	NO
Number of end stations	YES		NO	NO	NO	NO	NO	NO
Basic network topology	YES	NO		NO	NO	NO	YES	YES
Number of switches between end stations	YES	NO	NO		NO	NO	YES	YES
Throughput RTE	NO	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	NO		YES	NO
Time synchronization accuracy	NO	YES	NO	YES	NO	NO		NO
Redundancy recovery time	YES	NO	YES	YES	NO	NO	NO	

15.5.6.2.2   Delivery Time

The performance indicator delivery time can be calculated by Formula (69).

$$DT = TStack\_S + TQueue\_S + TEthernet\_S + TTrf\_S \times Ndata + \qquad (69)$$
$$TCable \times LCable + TSwitch \times NSwitch + TStack\_R$$

where

DT	is the delivery time;
TStack_S	is the sender stack processing time;
TQueue_S	is the sender queuing delay;
TEthernet_S	is the sender traversal time through MAC and Phy based on ISO/IEC/IEEE 8802-3;
TTrf_S	is the transfer time for an octet;
Ndata	is the length in octets of complete Ethernet frame;
TCable	is the cable delay;
LCable	is the cable length;
TSwitch	is the Switch delay;
NSwitch	is the Number of switches between end stations;
TStack_R	is the receiver stack processing time including Phy and MAC.

As shown in Formula (69):

- the number of end stations influences DT with queue delay;
- the number of switches between end stations influences DT. DT will be longer when the number of switches between end stations increases;
- the throughput RTE influences DT. That is, DT will be longer due to queue delay when Throughput RTE increases.

15.5.6.2.3   Number of end stations

If the delivery time is set to the bounded delivery time, then the maximum number of end stations is restricted.

15.5.6.2.4   Basic network topology

The basic network topology is designed in linear, star, ring or daisy-chain according to the delivery time in application.

If redundancy recovery time is allowed to use rapid spanning tree algorithm according to IEEE 802.1D, then the basic network topology can be designed in linear, star, ring or daisy-chain. For redundant ring topology, a single cable fault does not produce any failure, redundancy recovery time is zero.

15.5.6.2.5   Number of switches between end stations

The number of switches between end stations shall be designed to a minimum value so that delivery time, time synchronization accuracy and redundancy recovery accuracy meet the application demands.

15.5.6.2.6   Relation between Throughput RTE and Non-RTE bandwidth

The relation between Throughput RTE and Non-RTE bandwidth is specified in Formula (70).

$$NRTE\_BW = ((RateofEthernet - ThroughputRTE \times 8) / RateofEthernet) \times 100 \qquad (70)$$

where

NRTE_BW	is the non-RTE bandwidth, in %;
RateofEthernet	is the Ethernet data rate in Mbit/s;
ThroughputRTE	is the RTE throughput in octets/s.

Throughput RTE can be calculated by Formula (71).

$$ThroughputRTE = (\sum (RTEData + TSData + RMData)) / s \qquad (71)$$

where

ThroughputRTE	is the RTE throughput in octets/s;
RTEData	is the real-time data in octets;
TSData	is the time synchronization data in octets;
RMData	is the redundancy management data in octets.

15.5.6.2.7 Time synchronization accuracy

Time synchronization accuracy depends on synchronization cycle and switch delay. The synchronization cycle depends on the number of end stations and the switch delay depends on the number of switches between end stations.

15.5.6.2.8 Redundancy recovery time

The time to detect a failure is depends on the number of switches between end stations.

15.5.6.3 Consistent set of performance indicators

Table 231 specifies consistent set of PI included in this profile.

Table 231 – CP 14/3: Consistent set of PIs

performance indicator	Value	Constraints
Delivery time	100 µs	Star topology, no failure
	100 µs	Linear topology, no failure
	200 µs	Ring topology, no failure
Number of end stations	6	—
Number of switches between end stations	1	Star topology
	0	Linear topology
	0	Ring topology
Throughput RTE	3 840 000 octets/s	100 Mbit/s Ethernet (full-duplex)
Non-RTE bandwidth	0	—
Time synchronization accuracy	< 1 µs	—
Redundancy recovery time	n.a.	Star topology
	n.a.	Linear topology
	0 s	Ring topology

Table 232 specifies consistent set of PI included in this profile.

Table 232 – CP 14/3: Consistent set of PIs

performance indicator	value	constraints
Delivery time	250 μs	Star topology, no failure
	250 μs	Linear topology, no failure
	500 μs	Ring topology, no failure
Number of end stations	6	
Number of switches between end stations	1	Star topology
	0	Linear topology
	0	Ring topology
Throughput RTE	1 536 000 octets/s	100 Mbit/s Ethernet (full duplex)
Non-RTE bandwidth	84 %	100 Mbit/s Ethernet (full duplex)
Time synchronization accuracy	< 1 μs	—
Redundancy recovery time	n.a.	Star topology
	n.a.	Linear topology
	0 s	Ring topology

Table 233 specifies consistent set of PI included in this profile.

Table 233 – CP 14/3: Consistent set of PIs

performance indicator	value	Constraints
Delivery time	1 000 μs	Star topology, no failure
	1 000 μs	Linear topology, no failure
	2 000 μs	Ring topology, no failure
Number of end stations	80	—
Number of switches between end stations	3	Star topology
	0	Linear topology
	0	Ring topology
Throughput RTE	5 576 000 octets/s	100 Mbit/s Ethernet (full duplex)
Non-RTE bandwidth	40 %	100 Mbit/s Ethernet (full duplex)
Time synchronization accuracy	< 1 μs	—
Redundancy recovery time	300 ms	Star topology, IEEE 802.1D
	n.a.	Linear topology
	0	Ring topology

15.6 Profile 14/4

15.6.1 Physical layer

The Physical Layer of the EPA profile is according to ISO/IEC/IEEE 8802-3. EPA devices may use a data rate of 10 Mbit/s, 100 Mbit/s and higher. The topology shall be linear, star, ring or the combination of the above.

15.6.2 Data-link layer

The Data Link Layer shall be according to ISO/IEC/IEEE 8802-3, IEEE 802-1D.

In addition, EPA Communication Scheduling Management Entity (ECSME) is defined on ISO/IEC/IEEE 8802-3 data link services are defined in IEC 61158-3-14, and data link protocol to manage the deterministic communication in IEC 61158-4-14.

Table 234 defines the DLL service selection from IEC 61158-3-14 for profile 14/4.

Table 234 – CP 14/4: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	DL Service and concept	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DLL	YES	—
5	DL-management services	YES	—
5.1	Overview	Partial	Used when applicable
5.2	Non-periodic data annunciation	YES	—
5.3	EndofNonPeriodicDataSendingAnnunciation service	YES	—
5.4	DL-management for FRT applications	–	—

Table 235 defines the DLL protocol selections from IEC 61158-4-14 for CP14/4

Table 235 – CP 14/4: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbolsand abbreviations	Partial	Used when applicable
4	Overview of the DL-protocol	Partial	Used when applicable
4.1	General	Partial	Used when applicable
4.2	Services provided by the DL	YES	—
4.3	Structure of deterministic communication scheduling	YES	—
5	Procedure of deterministic communication scheduling	Partial	—
5.1	Overview	YES	—
5.2	State transitions	YES	—
5.3	State table	YES	—
5.4	Function descriptions	—	—
6	Structure and encoding of ECSME PDU	YES	—

15.6.3 Network layer

Internet standards RFC 791 (IP), RFC 826 (ARP), RFC 792 (ICMP) and their amendments and successors can be used.

15.6.4 Transport layer

Internet standard RFC 768 (UDP), RFC 793 (TCP) and their amendments and successors may be used. But for real-time applications, RFC 768 shall be used for field devices, bridges and master devices.

15.6.5 Application layer

15.6.5.1 AL service selection

The application layer services for profile 14/4 are defined in IEC 61158-5-14. Table 236 specifies the clauses included in this profile.

Table 236 – CP 14/4: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Concepts	Partial	Used when applicable
5	Data type ASE	YES	—
6	Communication model specification	YES	—

15.6.5.2 AL protocol selection

The application layer protocol for profile 14/4 is defined in IEC 61158-6-14. Table 237 specifies the clauses included in this profile.

Table 237 – CP 14/4: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	Partial	Used when applicable
3	Terms, definitions, symbols, abbreviations and conventions	Partial	Used when applicable
4	Abstract syntax	YES	—
4.1	Fixed format PDU description	YES	—
4.2	Object definitions in FAL management ASE	YES	—
4.3	Definition of objects used in Type 14 application access entity	YES	—
5	Transfer syntax	YES	—
5.1	Encoding of basic data types	YES	—
5.2	Encoding of Type 14 APDU header	YES	—
5.3	Encoding of FAL management entity service parameters	YES	—
5.4	Encoding of AAE Services	YES	—
6	Structure of FAL protocol state machines	YES	—
7	AP-Context state machine	YES	—
8	FAL management state machines	YES	—
9	Application access entity protocol machine	YES	—
10	Application relationship state machine	YES	—
11	DLL mapping protocol machine	YES	—

15.6.6   Performance indicatior selection

15.6.6.1   Performance indicator overview

Table 238 provides an overview of CP 14/4 performance indicators.

Table 238 – CP 14/4: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	—
Number of switches between end-stations	YES	—
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	YES	—
Non-time-based synchronization accuracy	NO	—
Redundancy recovery time	YES	—

15.6.6.2   Performance indicator dependencies

Table 239 specifies the performance indacator dependencies for CP 14/4.

Table 239 – CP 14/4: PI dependency matrix

Dependent PI	Influencing PI							
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accurancy	Redundancy recovery time
Delivery time		YES	NO	YES	YES	NO	NO	NO
Number of end-stations	YES		NO	NO	NO	NO	NO	NO
Basic network topology	YES	NO		NO	NO	NO	YES	YES
Number of switches between end-stations	YES	NO	NO		NO	NO	YES	YES
Throughput RTE	NO	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	NO	NO		YES	NO
Time synchronization accuracy	NO	YES	NO	YES	NO	NO		NO
Redundancy recovery time	YES	NO	YES	YES	NO	NO	NO	

15.6.6.2.1   Delivery Time

The performance indicator delivery time can be calculated by Formula (72).

$$DT = TStack\_S + TQueue\_S + TEthernet\_S + TTrf\_S \times Ndata + TCable \times \quad (72)$$
$$LCable + TSwitch \times NSwitch + TStack\_R$$

where

DT	is the delivery time;
TStack_S	is the sender stack processing time;
TQueue_S	is the sender queuing delay, the max queue delay is equal to cycle time, the minimum queue delay is 0;
TEthernet_S	is the sender traversal time through MAC and Phy based on ISO/IEC/IEEE 8802-3;
TTrf_S	is the transfer time for an octet;
Ndata	is the length in octets of complete Ethernet frame;
TCable	is the cable delay;
LCable	is the cable length;
TSwitch	is the Switch delay;
NSwitch	is the Number of switches between end-stations;
TStack_R	is the receiver stack processing time including Phy and MAC.

As shown in Formula (72),

- the number of end-stations influences DT with queue delay;

- the number of switches between end-stations influences DT. DT will be enlarged when the number of switches between end-stations increases;

- the throughput RTE influences DT. That is, DT will be enlarged due to queue delay when Throughput RTE increases. The max queue delay is equal to cycle time, and the minimum queue delay is 0.

15.6.6.2.2   Number of end-stations

If the delivery time is set to the bounded delivery time, then the maximum number of end-stations is restricted.

15.6.6.2.3   Basic network topology

The basic network topology is designed in linear, star, ring or daisy-chain according to the delivery time in application. If the delivery time is preset to the boundary delivery time, the basic network topology shall be set to a hierarchical star.

If the time synchronization accuracy is set to the minimum value, the basic network topology shall be set to a hierarchical star.

If redundancy recovery time is allowed to use rapid spanning tree algorithm according to IEEE 802.1D, then the basic network topology can be designed in linear, star, ring or daisy-chain.

15.6.6.2.4   Number of switches between end-stations

The number of switches between end-stations shall be designed to a minimum value so that delivery time, time synchronization accuracy and redundancy recovery accuracy meet the application requirements.

15.6.6.2.5   Throughput RTE and Non-RTE bandwidth

See 15.3.6.2.5.

15.6.6.2.6 Time synchronization accuracy

Time synchronization accuracy depends on synchronization cycle and switch delay. The synchronization cycle depends on the number of end-stations and the switch delay depends on the number of switches between end-stations.

15.6.6.2.7 Redundancy recovery time

The time to detect a failure depends on the number of switches between end-stations.

15.6.6.3 Consistent set of performance indicators

Table 240 specifies a consistent set of PI included in this profile.

Table 240 – CP 14/4: Consistent set of PIs

Performance indicator	Value	Constraints
Delivery Time	100 µs	Without failure
	500 µs	One frame lost
Number of end-stations	6	Star topology with switches connected
Number of switches between end-stations	1	—
Throughput RTE	9 248 000 octets/s	—
Non-RTE bandwidth	25 %	100 Mbit/s Ethernet (full duplex)
Time synchronization accuracy	< 1 µs	—
Redundancy recovery time	< 300 ms	Using IEEE 802.1D

16 Communication Profile Family 15 (MODBUS-RTPS) – RTE communication profiles

16.1 General overview

Communication Profile Family 15 defines profiles based on ISO/IEC/IEEE 8802-3, RFC 791 (IP), RFC 793 (TCP), RFC 768 (UDP), IEC 61158-5-15 and IEC 61158-6-15, which specify the communication system protocols commonly known as Modbus® [14] and Modbus TCP, and RTPS (Real-Time Publish-Subscribe).

In this document, the following communication profiles are specified for CPF 15:

– Profile 15/1

Is a profile using Modbus TCP

– Profile 15/2

Is a profile using RTPS.

For both profiles the communication is assumed to be full-duplex, with network topologies built via switches.

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[14] Modbus is a trademark of Schneider Automation Inc registered in the United States of America and other countries. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trademark Modbus. Use of the trademark Modbus requires permission from Schneider Automation Inc.

These communication profiles can be active at the same time on the same device and network, and as such they do not constitute alternative profiles, but can provide complementary and concurrent functionality.

16.2 Profile 15/1

16.2.1 Physical layer

The physical layer of CP 15/1 is as specified in ISO/IEC/IEEE 8802-3.

16.2.2 Data-link layer

The data-link layer of CP 15/1 is as specified in ISO/IEC/IEEE 8802-3.

16.2.3 Application layer

16.2.3.1 General

The application layer of CP 15/1 is mapped on TCP (RFC 793), using TCP Port Number 502, registered with IANA, over IP (RFC 791), as described in IEC 61158-5-15 and IEC 61158-6-15.

16.2.3.2 AL service selection

The application layer services are defined in IEC 61158-5-15. Table 241 shows the subclauses included in this profile.

Table 241 – CP 15/1: AL service selection

Clause	Header	Presence	Constraints
Whole document	Application layer services definition (Type 15)	Partial	Subclauses qualified as Common or Client/Server

16.2.3.3 AL protocol selection

The application layer protocols are defined in IEC 61158-6-15. Table 242 shows the subclauses included in this profile.

Table 242 – CP 15/1: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Application layer protocol specification (Type 15)	Partial	Subclauses qualified as Common or Client/Server

16.2.4 Performance indicator selection

16.2.4.1 Performance indicator overview

Table 243 provides an overview of the CP 15/1 performance indicators.

Table 243 – CP 15/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	—
Number of switches between end-stations	YES	—
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	YES	Provided with NTP (RFC 1305)
Non-time-based synchronization accuracy	YES	—
Redundancy recovery time	YES	—

16.2.4.2   Performance indicator dependencies

Table 244 provides the CP 15/1 performance indicator dependency matrix.

Table 244 – CP 15/1: PI dependency matrix

Dependent PI	Influencing PI								
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Time synchroni-zation accurancy	Non-time-based synchronization accurancy	Redundancy recovery time
Delivery time		NO	YES 16.2.4.2.1 16.2.4.2.23	YES 16.2.4.2.23	NO	NO	NO	NO 16.2.4.2.2	YES 16.2.4.2.3
Number of end-stations	NO		NO 16.2.4.2.4	YES 16.2.4.2.5	NO	NO	NO	NO	NO
Basic network topology	NO	YES 16.2.4.2.6		YES 16.2.4.2.7	NO	NO	NO	NO	NO
Number of switches between end-stations	NO	YES 16.2.4.2.8	YES 16.2.4.2.9		NO	NO	NO	NO	NO
Throughput RTE	NO	NO	NO	NO		YES 16.2.4.2.10	NO	NO 16.2.4.2.11	YES 16.2.4.2.12
Non-RTE bandwidth	NO	NO	NO	NO	YES 16.2.4.2.13		NO	NO	YES 16.2.4.2.14
Time synchronization accuracy	NO	NO	YES 16.2.4.2.15	YES 16.2.4.2.16	NO	NO		NO	YES 16.2.4.2.17
Non-time-based synchronization accuracy	NO	NO	YES 16.2.4.2.18	YES 16.2.4.2.19	NO	NO	NO		YES 16.2.4.2.20
Redundancy recovery time	NO	NO	YES 16.2.4.2.21	YES 16.2.4.2.22	NO	NO	NO	NO	

16.2.4.2.1 Delivery time and basic network topology

The following network topologies are supported:

- Star,
- Linear (embedded or bus),
- Ring,
- Redundant ring,
- Mesh.

The network topology influences the delivery time indirectly by influencing the number of switches to be traversed and the queuing and directly when supporting redundancy, by reacting differently in case of failures.

CP 15/1 has no switch technology dependencies.

16.2.4.2.2 Delivery time and non-time-based synchronization accuracy

In a scan situation it may affect the delivery time of the response/confirmation, due to queues on switches. It does not affect non-scan situations.

16.2.4.2.3 Delivery time and redundancy recovery time

This dependency is applicable only when the network topology supports redundancy.

16.2.4.2.4 Number of end-stations and basic network topology

Indirect dependency bounded in practice by the number of switches that have to be traversed, given the same number of connected end-stations, for different topologies.

16.2.4.2.5 Number of end-stations and number of switches between end-stations

The number of end-stations, for a given topology, depends on the number and kind of switches: there must be enough switches with enough ports.

16.2.4.2.6 Basic network topology and number of end-stations

Some topologies, e.g. linear, have limits on the number of nodes.

16.2.4.2.7 Basic network topology and number of switches between end-stations

The realization of some topologies requires a minimum number of switches, with a minimum number of ports, given a number of end-stations.

16.2.4.2.8 Number of switches between end-stations and number of end-stations

For certain topologies, like linear, the number of switches between end-stations depends on the number of end-stations. Considering the limit on the number of ports per switch this dependency is generally present.

16.2.4.2.9 Number of switches between end-stations and basic network topology

Some topologies allow for fewer switches given a number of nodes, e.g. the star topology.

16.2.4.2.10 Throughput RTE and non-RTE bandwidth

The application is responsible for limiting non-RTE traffic, which can otherwise impact the throughput RTE.

16.2.4.2.11 Throughput RTE and non-time-based synchronization accuracy

In a scan situation the throughput may be affected, due to queues on switches. It is not affected in non-scan situations.

16.2.4.2.12 Throughput RTE and redundancy recovery time

There is throughput RTE disruption when recovery takes place.

16.2.4.2.13 Non-RTE bandwidth and throughput RTE

The application is responsible for limiting RTE traffic if Not-RTE bandwidth has to be made available.

16.2.4.2.14 Non-RTE bandwidth and redundancy recovery time

There is non-RTE bandwidth disruption when recovery takes place.

16.2.4.2.15 Time synchronization accuracy and basic network topology

Some topologies, e.g. linear, affect the NTP accuracy due to the presence of variable delays.

16.2.4.2.16 Time synchronization accuracy and number of switches between end-stations

Switches cause variable delays, affecting the NTP accuracy.

16.2.4.2.17 Time synchronization accuracy and redundancy recovery time

There is disruption when recovery takes place.

16.2.4.2.18 Non-time-based synchronization accuracy and basic network topology

Some topologies, e.g. the star topology, allow for a better non-time-based synchronization accuracy.

16.2.4.2.19 Non-time-based synchronization accuracy and number of switches between end-stations

Switches cause variable delays, affecting the accuracy.

16.2.4.2.20 Non-time-based synchronization accuracy and redundancy recovery time

There is disruption when recovery takes place.

16.2.4.2.21 Redundancy recovery time and basic network topology

The redundancy recovery time, when supported by the topology, is topology dependent.

16.2.4.2.22 Redundancy recovery time and number of switches between end-stations

The redundancy recovery time, when supported by the topology, is dependent on the number of switches.

16.2.4.2.23 Calculation of delivery time

The performance indicator delivery time can be calculated by Formula (73):

$$DT = STT\_s + N\_Sw \times TD\_Sw + (N\_Sw + 1) \times T\_wire \times D\_size + STT\_r \qquad (73)$$

where

DT	is the delivery time;
STT_s	is the stack traversal time of the sender;
N_Sw	is the number of switches between end-stations;
TD_Sw	is the time delay in switch;
T_wire	is the time per octet on a wire segment;
D_size	is the data size in octets;
STT_r	is the stack traversal time of the receiver.

The performance indicator delivery time, in case of one lost frame, can be calculated by Formula (74):

$$DT\_lf = 2 \times DT + RTO \tag{74}$$

where

DT_lf	is the delivery time when a frame is lost;
DT	is as computed in Formula (73);
RTO	is the TCP retransmission time out parameter.

NOTE   RTO is a dynamic parameter, computed with an algorithm configured using an initial value and a minimum value, see RFC 2988 (Computing TCP's Retransmission Timer). The configuration values of RTO differ between TCP implementations.

16.3   Profile 15/2

16.3.1   Physical layer

The physical layer of CP 15/2 is as specified in ISO/IEC/IEEE 8802-3.

16.3.2   Data-link layer

The data-link layer of CP 15/2 is as specified in ISO/IEC/IEEE 8802-3.

16.3.3   Application layer

16.3.3.1   General

The application layer of CP 15/2 is mapped on UDP (RFC 768), over IP (RFC 791), as described in IEC 61158-5-15 and IEC 61158-6-15.

CP 15/2 uses three UDP ports. The actual values can be configured in the field by setting the parameters 'portBaseNumber' and 'portGroupNumber' as from Formulae (75), (76) and (77). Implementations of CP 15/2 must support configuring these two parameters.

$$port1 = portBaseNumber + 10 \times portGroupNumber \tag{75}$$

$$port2 = 1 + portBaseNumber + 10 \times portGroupNumber \tag{76}$$

$$port3 = 2 + portBaseNumber + 10 \times portGroupNumber \tag{77}$$

The default configuration is to set the values portBaseNumber = 7400 and portGroupNumber = 0, which results in the use of ports 7400, 7401, and 7402. These ports are registered with IANA as:

- 7400 RTPS Discovery,
- 7401 RTPS Data-Distribution User-Traffic,
- 7402 RTPS Data-Distribution Meta-Traffic.

16.3.3.2   AL service selection

The application layer services are defined in IEC 61158-5-15. Table 245 shows the subclauses included in this profile.

Table 245 – CP 15/2: AL service selection

Clause	Header	Presence	Constraints
Whole document	Application layer services definition (Type 15)	Partial	Subclauses qualified as Common or Publish/Subscribe

16.3.3.3   AL protocol selection

The application layer protocols are defined in IEC 61158-6-15. Table 246 shows the subclauses included in this profile.

Table 246 – CP 15/2: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Application layer protocol specification (Type 15)	Partial	Subclauses qualified as Common or Publish/Subscribe

16.3.4   Performance indicator selection

16.3.4.1   Performance indicator overview

Table 247 provides an overview of the CP 15/2 performance indicators.

Table 247 – CP 15/2: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	—
Number of switches between end-stations	YES	—
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Redundancy recovery time	YES	—

16.3.4.2   Performance indicator dependencies

Table 248 provides the CP 15/2 performance indicator dependency matrix.

Table 248 – CP 15/2: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Number of switches between end-stations	Throughput RTE	Non-RTE bandwidth	Redundancy recovery time
Delivery time		NO	YES 16.3.4.2.1 16.3.4.2.15	YES 16.3.4.2.15	NO	NO	YES 16.3.4.2.2
Number of end-stations	NO		NO 16.3.4.2.3	YES 16.3.4.2.4	NO	NO	NO
Basic network topology	NO	YES 16.3.4.2.5		YES 16.3.4.2.6	NO	NO	NO
Number of switches between end-stations	NO	YES 16.3.4.2.7	YES 16.3.4.2.8		NO	NO	NO
Throughput RTE	NO	NO	NO	NO		YES 16.3.4.2.9	YES 16.3.4.2.10
Non-RTE bandwidth	NO	NO	NO	NO	YES 16.3.4.2.11		YES 16.3.4.2.12
Redundancy recovery time	NO	NO	YES 16.3.4.2.13	YES 16.3.4.2.14	NO	NO	

16.3.4.2.1 Delivery time and basic network topology

The following network topologies are supported:

- Star,
- Linear (embedded or bus),
- Ring,
- Redundant ring,
- Mesh.

The network topology influences the delivery time indirectly by influencing the number of switches to be traversed and the queuing and directly when supporting redundancy, by reacting differently in case of failures.

CP 15/2 has no switch technology dependencies.

16.3.4.2.2 Delivery time and redundancy recovery time

This dependency is applicable only when the network topology supports redundancy.

16.3.4.2.3 Number of end-stations and basic network topology

Indirect dependency bounded in practice by the number of switches that have to be traversed, given the same number of connected end-stations, for different topologies.

16.3.4.2.4   Number of end-stations and number of switches between end-stations

The number of end-stations, for a given topology, depends on the number and kind of switches: there must be enough switches with enough ports.

16.3.4.2.5   Basic network topology and number of end-stations

Some topologies, e.g. linear, have limits on the number of nodes.

16.3.4.2.6   Basic network topology and number of switches between end-stations

The realization of some topologies requires a minimum number of switches, with a minimum number of ports, given a number of end-stations.

16.3.4.2.7   Number of switches between end-stations and number of end-stations

For certain topologies, like linear, the number of switches between end-stations depends on the number of end-stations. Considering the limit on the number of ports per switch this dependency is generally present.

16.3.4.2.8   Number of switches between end-stations and basic network topology

Some topologies allow for fewer switches given a number of nodes, e.g. the star topology.

16.3.4.2.9   Throughput RTE and non-RTE bandwidth

The application is responsible for limiting non-RTE traffic, which can otherwise impact the throughput RTE.

16.3.4.2.10   Throughput RTE and redundancy recovery time

There is throughput RTE disruption when recovery takes place.

16.3.4.2.11   non-RTE bandwidth and throughput RTE

The application is responsible for limiting RTE traffic if non-RTE bandwidth has to be made available.

16.3.4.2.12   not-RTE bandwidth and redundancy recovery time

There is non-RTE bandwidth disruption when recovery takes place.

16.3.4.2.13   Redundancy recovery time and basic network topology

The redundancy recovery time, when supported by the topology, is topology dependent.

16.3.4.2.14   Redundancy recovery time and number of switches between end-stations

The redundancy recovery time, when supported by the topology, is dependent on the number of switches.

16.3.4.2.15   Calculation of delivery time

The performance indicator delivery time can be calculated using the Formulae (78), (79) and (80).

$$STT\_s = STT\_s1 + SST\_s2 \times D\_size \tag{78}$$

where

STT_s	is the stack traversal time of the sender;
STT_s1	is the part of the stack traversal time of the sender that is independent of the data size;
STT_s2	is the part of the stack traversal time of the sender that depends linearly on the size of the data D_size; this is because the stack performs a memory copy so it is affected by the speed of the memory system;
D_size	is the data size in octets.

$$STT\_r = STT\_r1 + SST\_r2 \times D\_size \tag{79}$$

where

STT_r	is the stack traversal time of the receiver;
STT_r1	is the part of the stack traversal time of the receiver that is independent of the data size;
STT_r2	is the part of the stack traversal time of the receiver that depends linearly on the size of the data D_size; this is because the stack performs a memory copy so it is affected by the speed of the memory system;
D_size	is the data size in octets.

$$DT = STT\_s + N\_Sw \times TD\_Sw + (N\_Sw + 1) \times T\_wire \times D\_size + STT\_r \tag{80}$$

where

DT	is the delivery time;
STT_s	is the stack traversal time of the sender;
N_Sw	is the number of switches between end-stations;
TD_Sw	is the time delay in switch;
T_wire	is the time per octet on a wire segment;
D_size	is the data size in octets;
STT_r	is the stack traversal time of the receiver.

The performance indicator delivery time, in case of one lost frame, depends on how the communication between end-stations under consideration is configured:

a) best effort;

b) reliable periodic;

c) reliable with heartbeat.

If best effort, then the delivery time in case of a lost frame does not apply, since that frame is not retransmitted.

If reliable periodic then, in case of one lost frame, the performance indicator delivery time can be calculated by the Formula (81).

$$DT\_lfp = 2 \times DT + DT\_n + T \tag{81}$$

where

DT_lfp	is the delivery time when a frame is lost and the configuration is reliable periodic;
DT	is as computed in Formula (80);
DT_n	is the delivery time for the NACK message, computed again using Formula (80), but with a D_size of 16 octets;
T	is the period, which is a configured parameter.

NOTE 1   A typical value for the period T is 10 ms.

If reliable with heartbeat then, in case of one lost frame, the performance indicator delivery time can be calculated by the Formula (82)

$$DT\_lfh = 2 \times DT + DT\_n + H \tag{82}$$

where

DT_lfh	is the delivery time when a frame is lost and the configuration is reliable with heartbeat;
DT	is as computed in Formula (80);
DT_n	is the delivery time for the NACK message, computed again using Formula (80), but with a D_size of 16 octets;
H	is the period of the heartbeat, which is a configured parameter.

NOTE 2   A typical value for the period heartbeat is between 100 ms and 1 s (it has a system monitoring role and does not carry any data).

17 Communication Profile Family 16 (SERCOS[15])- RTE communication profiles

17.1 General overview

Communication Profile Family 16 defines profiles based on IEC 61158 series, protocol Type 16 and Type 19.

The CPF 16 consists of three communication profiles (CP).

– Profile 16/1 (SERCOS I)

   This profile is based on fibre-media physical layers and operates at 2 Mbit/s and 4 Mbit/s. Refer to IEC 61784-1.

– Profile 16/2 (SERCOS II)

   This profile is similar to 16/1, but operates also at 8 Mbit/s and 16 Mbit/s, and provides for additional features. Refer to IEC 61784-1.

– Profile 16/3 (SERCOS III)

   This profile is based on ISO/IEC/IEEE 8802-3 (Ethernet) MAC and physical layers; it provides again for additional features.

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[15] SERCOS is a trade name of Sercos International e.V. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

17.2 Profile 16/3 (SERCOS III)

17.2.1 Physical layer

The physical layer is based on standard Ethernet hardware according to ISO/IEC/IEEE 8802-3. CP 16/3 (SERCOS III) devices shall use a data rate of 100 Mbit/s, and shall be connected in a ring or a line topology. Any combination of full-duplex, 100Base-TX with auto crossover function (wire, 2 twisted pairs), as well as 100Base-FX (optical fibre) may be used.

When using cables, they shall be rated Cat5e or better, and shielded in an appropriate way (FTP, STP or SFTP) depending upon EMC constraints.

17.2.2 Data-link layer

17.2.2.1 General

CP 16/3 profile shall use standard Ethernet ISO/IEC/IEEE 8802-3 frames tagged with the Ethertype 0x88CD.

17.2.2.2 DLL service selection

The data-link layer services are defined in IEC 61158-3-19. Table 249 shows the subclauses included in this profile.

Table 249 – CP 16/3: DLL service selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 19)	YES	—

17.2.2.3 DLL protocol selection

The data-link layer protocols are defined in IEC 61158-4-19. Table 250 shows the subclauses included in this profile.

Table 250 – CP 16/3: DLL protocol selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 19)	YES	—

17.2.3 Application layer

17.2.3.1 AL service selection

The application layer services are defined in IEC 61158-5-19. Table 251 shows the subclauses included in this profile.

Table 251 – CP 16/3: AL service selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 19)	YES	—

17.2.3.2 AL protocol selection

The application layer protocol is defined in IEC 61158-6-19. Table 252 shows the subclauses included in this profile.

Table 252 – CP 16/3: AL protocol selection

Clause	Header	Presence	Constraints
Whole document	Data link protocol specification (Type 19)	YES	—

17.2.4 Performance indicator selection

17.2.4.1 Performance indicator overview

Table 253 gives an overview on the applicable performance indicators for CP 16/3.

Table 253 – CP 16/3: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	—
Number of end-stations	YES	—
Basic network topology	YES	—
Number of switches between end-stations	NO	Switches shall not be used
Throughput RTE	YES	—
Non-RTE bandwidth	YES	—
Time synchronization accuracy	NO	—
Non-time-based synchronization accuracy	YES	—
Redundancy recovery time	YES	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

17.2.4.2 Performance indicator dependencies

Table 254 gives an overview on the dependencies of the performance indicators.

Table 254 – CP 16/3: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Non time- based synchronization accurary	Redundency recovery time
Delivery time		YES 17.2.4.2.1	NO	YES 17.2.4.2.1	YES 17.2.4.2.1	NO	NO
Number of end-stations	YES		NO	YES	YES	NO	NO
Basic network topology	NO	NO		NO	NO	NO	NO
Throughput RTE	NO	NO	NO		YES 17.2.4.2.5	NO	NO
Non-RTE bandwidth	NO	NO	NO	YES 17.2.4.2.5		NO	NO
Non-time-based synchronization accuracy	NO	YES 17.2.4.2.6	NO	NO	NO		NO
Redundancy recovery time	NO	NO	YES 17.2.4.2.7	NO	NO	NO	

17.2.4.2.1 Calculation of delivery time

The performance indicator delivery time can be calculated by Formula (83).

$$DT = ct + STTs + STTr + fr \tag{83}$$

where

DT	is the delivery time;
ct	is the cycle_time (according to 17.2.4.2.2);
$STTs$	is the sender stack traversal time including Phy and MAC (according to 17.2.4.2.4);
$STTr$	is the receiver stack traversal time including Phy and MAC (according to 17.2.4.2.4);
fr	is the frame runtime (according to 17.2.4.2.3);
STT	is the stack traversal time including Phy and MAC .

EXAMPLE:

Cycle_Time = 31,25 μs; Frame Runtime = 9 μs; STTs << 1 μs; STTt << 1 μs

Delivery time = 31,25 μs + 9 μs = 40,25 μs

17.2.4.2.2 Calculation of cycle time

CP 16/3 is a communication technology with fixed, discrete communication cycles. The cycle time is defined as multiples and submultiples of 250 μs according to Formula (84).

$$ct = \begin{cases} N \times 250 \ \mu s \ where \ N \geq 1 \ and \ N \leq 260 \ 000 \\ \dfrac{250 \ \mu s}{N} \ where \ N = 2, \ 4 \ or \ 8 \end{cases} \qquad (84)$$

where

ct	is the cycle_time configured for the network segment;
N	is an integer value.

This means that the cycle time may be selected between 31,25 μs and 65 ms. It may be shorter, but shall not be longer. In any case, the selected cycle time shall be greater than the minimum cycle time, as shown in Formula (85).

$$ct > mct \qquad (85)$$

where

ct	is the cycle_time configured for the network segment;
mct	is the minimum cycle time (according to Formula (86)).

The minimum cycle time of an application depends on the number of CP 16/3 nodes, the amount of real-time data exchanged between these nodes and the number of Ethernet frames that are used to transport the amount of real-time data between these nodes.

The minimum cycle time can be calculated by Formula (86).

$$mct = tt \times data + st \times nf \qquad (86)$$

where

mct	is the minimum_cycle_time;
tt	is the transfer time (80 ns/octet);
data	Is the data to be transmitted in one cycle (including the complete Ethernet frame);
st	is the separation time per frame;
nf	is the number of frames.

The number of frames is in a range between 2 and 8 depending on the amount of data to be transmitted and the number of nodes.

EXAMPLE

Transfer time = 80 ns/octet (100 Mbit/s); data = 336 octets; separation time per frame = 1 μs; number of frames = 2

Minimum cycle time: mct = 80 ns × 336 octets + 1 μs × 2 = 26,88 μs + 2 μs = 28,88 μs

Selected cycle time: ct = 31,25 μs > 28,88 μs

17.2.4.2.3　Calculation of the frame runtime

The frame runtime depends on the cable delay and the propagation delay (signal delay) in the forwarding nodes. Forwarding nodes are intermediate nodes between the sending and receiving node in a ring or line topology.

The frame runtime can be calculated by Formula (87)).

$$fr = cd \times clt + \sum_{i=1}^{nn} pd_i \qquad (87)$$

where

fr	is the frame runtime;
cd	is the cable delay;
clt	is the total cable length;
nn	is the number of nodes;
pd	is the propagation delay (signal delay) of a forwarding node.

EXAMPLE

Cable delay = 5 ns/m; cable length = 900 m; propagation delay = 0,5 μs; number of nodes = 9

Frame runtime = 5 ns/m × 900 m + 9 × 0,5 μs = 9,0 μs

17.2.4.2.4 Calculation of Sender and Receiver Stack Traversal Time

The sender and receiver stack traversal time are implementation specific and cannot be calculated by a formula. Real-time data is not moved through a sender and receiver stack. Instead the data is exchanged between the application and the communication controller by means of a shared memory which allows a fast and efficient access to the data.

17.2.4.2.5 Throughput RTE and non-RTE bandwidth

The throughput RTE and the non-RTE bandwidth are directly dependent on each other. When cycle times below 250 μs are configured (125 μs, 62,5 μs, 31,25 μs) only real-time data can be transmitted (non-RTE bandwidth = 0). For cycle times of 250 μs and higher, the share of non-RTE bandwidth in relation to the available bandwidth of 100 Mbit/s can be freely configured.

EXAMPLE 1

Cycle time = 250 μs, time slot for real-time data: 125 μs, time slot IP channel: 125 μs

Non-RTE bandwidth = 50 %, throughput RTE < 50 Mbit/s

EXAMPLE 2

Cycle time = 500 μs, time slot for real-time data: 125 μs, time slot IP channel: 375 μs

Non-RTE bandwidth = 75 %, throughput RTE < 25 Mbit/s

17.2.4.2.6 Non-time based synchronization accuracy

The synchronization accuracy depends on the accuracy of the Ethernet hardware which influences the exact point of time when the synchronization pattern is received by the node. The synchronization pattern is part of the MDT0 telegram which is sent once per communication cycle.

The accuracy can be calculated by Formula (88).

$$ac = ma + \sum_{i=1}^{nn-1} sa_i \tag{88}$$

where

ac	is the non-time based synchronization accuracy;
ma	is the synchronization accuracy of the master device;
sa	is the synchronization accuracy of one slave device;
nn	the number of nodes; (nn-1) is the number of slaves, in a line topology.

EXAMPLE 1   Master device with hardware-based synchronization

ma = 50 ns, 10 slave devices each with a synchronization accuracy of 50 ns

nslave = 10 slave devices each with a synchronization accuracy of 50 ns (equivalent to 20 slaves in a ring configuration)

ac = 50 ns + 10 × 50 ns = 550 ns

EXAMPLE 2   Master device with Standard Ethernet hardware and software-based synchronization

ma = 40 μs, 10 slave devices each with a synchronization accuracy of 50 ns

*n*slave = 10 slave devices each with a synchronization accuracy of 50 ns (equivalent to 20 slaves in a ring configuration)

ac = 40 μs + 10 × 50 ns = 40,5 μs

17.2.4.2.7   Redundancy recovery time

In the ring topology, a single permanent fault does not produce any failure. The ring is immediately split into two lines. In this case, the recovery time is zero.

17.2.4.3   Consistent set of performance indicators

Table 255 shows the consistent set of performance indicators for a scenario where the minimal cycle time of 31,25 μs is configured in a ring topology. In this scenario it is assumed that 9 end-stations (1 master end-station and 8 slave end-stations) are set up in such a way that each node produces and consumes up to 10 octets each including control and status words (4 octets each), that is 20 real-time octets per node.

Table 255 – CP 16/3: Consistent set of PIs with a minimum cycle time of 31,25 µs

Performance indicator	Value	Constraints
Delivery time	< 39,8 µs	Cable length between all end-stations 100 m (worst case) Cycle time set to 31,25 µs Frame runtime: 9 µs
Number of end-stations	≤ 9	1 master end-station, 8 slave end-stations
Number of switches between end-stations	0	Switches shall not be used
Throughput RTE	≤ 11 520 000 octets/s	≤ 10/10 real-time octets per slave end-station
Non-RTE bandwidth	0	For cycle times below 250 µs, non-RTE traffic is not supported
Non-time-based synchronization accuracy	< 1 µs or < 50 µs	< 1 µs (high performance synchronization), < 50 µs (low performance synchronization)
Redundancy recovery time	0	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

Table 256 shows the consistent set of performance indicators for a scenario where the cycle time of 500 µs is configured in a ring topology. In this scenario it is assumed that 185 end-stations (1 master end-station and 184 slave end-stations) are set up in such a way that each node produces and consumes up to 10 octets each including control and status words (4 octets each), that is 20 real-time octets per node. Non-RTE traffic is not used.

Table 256 – CP 16/3: Consistent set of PIs with a cycle time of 500 µs (real-time only)

Performance indicator	Value	Constraints
Delivery time	< 677 µs	Cable length between all end-stations 100 m (worst case) Cycle time set to 500 µs Frame runtime: 185 µs
Number of end-stations	≤ 185	1 master end station, 184 slave end-stations
Number of switches between end-stations	0	Switches shall not be used
Throughput RTE	≤ 12 192 000 octets/s	≤ 10/10 real-time octets per slave end-station
Non-RTE bandwidth	0	In this scenario, non-RTE traffic is not configured although possible
Non-time-based synchronization accuracy	< 1 µs or < 50 µs	< 1 µs (high performance synchronization), < 50 µs (low performance synchronization)
Redundancy recovery time	0	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

Table 257 shows the consistent set of performance indicators for a scenario where the cycle time of 500 µs is configured in a ring topology. In this scenario it is assumed that 139 end-stations (1 master end-station and 138 slave end-stations) are set up in such a way that each node produces and consumes up to 10 octets each including control and status word (4 octets each), that is 20 real-time octets per node. The non-RTE traffic is used and uses 25 % of the available bandwidth (slot for non-real-time data: 125 µs = 25 % of 500 µs).

**Table 257 – CP 16/3: Consistent set of PIs with
a cycle time of 500 μs (real-time and non-real-time)**

Performance indicator	Value	Constraints
Delivery time	< 513 μs	Cable length between all end-stations 100 m (worst case) Cycle time set to 500 μs Frame runtime: 139 μs
Number of end-stations	≤ 139	1 master end-station, 138 slave end-stations
Number of switches between end-stations	0	Switches shall not be used
Throughput RTE	≤ 9 248 000 octets/s	≤ 10/10 real-time octets per slave end-station
Non-RTE bandwidth	≤ 3 125 000 octets/s	25 % of the bandwidth is used for non-RTE traffic (IP channel is 125 μs wide)
Non-time-based synchronization accuracy	< 1 μs or < 50 μs	< 1 μs (high performance synchronization), < 50 μs (low performance synchronization)
Redundancy recovery time	0	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

Table 258 shows the consistent set of performance indicators for a scenario where the cycle time of 500 μs is configured in a ring topology. In this scenario it is assumed that 101 end-stations (1 master end-station and 100 slave end-stations) are set up in such a way that each end slave node produces 24 octets and consumes 8 octets, including control and status words respectively (4 octets each). Such a scenario fits particularly well to power drive system applications as described in the IEC 61800 series. The non-RTE traffic is used and uses 25 % of the available bandwidth (slot for non-real-time data: 125 μs = 25 % of 500 μs).

**Table 258 – CP 16/3: Consistent set of PIs with non symmetrical data
throughput and a cycle time of 500 μs (real-time and non-real-time)**

Performance indicator	Value	Constraints
Delivery time	< 474 μs	Cable length between all end-stations 100 m (worst case) Cycle time set to 500 μs Frame runtime: 101 μs
Number of end-stations	≤ 101	1 master end-station, 100 slave end-stations
Number of switches between end-stations	0	Switches shall not be used
Throughput RTE	≤ 9 248 000 octets/s	≤ 10/10 real-time octets per slave end-station
Non-RTE bandwidth	≤ 3 125 000 octets/s	25 % of the bandwidth is used for non-RTE traffic (IP channel is 125 μs wide)
Non-time-based synchronization accuracy	< 1 μs or < 50 μs	< 1 μs (high performance synchronization), < 50 μs (low performance synchronization)
Redundancy recovery time	0	In the ring topology, a single permanent fault does not produce any failure. In this case, the recovery time is zero

18 Communication Profile Family 17 (RAPIEnet) – RTE communication profiles

18.1 General overview

Communication Profile Family 17 (CPF 17) defines one communication profile based on the IEC 61158 series protocol Type 21. This profile corresponds to the communication system commonly known as RAPIEnet.

- Profile 17/1 (RAPIEnet)

This profile is based on ISO/IEC/IEEE 8802-3 (Ethernet) MAC and physical layers and selections of AL, and DLL services and protocol definitions from the IEC 61158 series Type 21.

Table 259 shows the overview of RAPIEnet profile set.

Table 259 – CPF 17: Overview of profile sets

Layer	Profile 17/1
Application	IEC 61158-5-21, IEC 61158-6-21
Data-link	IEC 61158-3-21, IEC 61158-4-21
Physical	ISO/IEC/IEEE 8802-3

18.2 Profile 17/1

18.2.1 Physical layer

The physical layer shall be according to ISO/IEC/IEEE 8802-3.

The data rate shall be at least 100 Mbit/s and full-duplex mode shall be used at least for one port.

The auto negotiation and crossover function (see ISO/IEC/IEEE 8802-3) shall be used.

18.2.2 Datalink layer

18.2.2.1 DLL services selection

Table 260 specifies the DLL service selection within IEC 61158-3-21.

Table 260 – CP 17/1: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, symbols, abbreviations and conventions	Partial	If applicable
4	Data-link layer services and concepts	YES	—
5	Data-link management services	YES	—
6	MAC control service	YES	—
7	Ph-control service	YES	—

18.2.2.2 DLL protocol selection

Table 261 specifies the DLL protocol selection within IEC 61158-4-21.

Table 261 – CP 17/1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, symbols and abbreviations	Partial	If applicable
4	Overview of the data-link protocol	YES	—
5	General structure and encoding	YES	—
6	DLPDU structure and procedure	YES	—
7	DLE elements of procedure	YES	—
8	Constants and error codes	YES	—

18.2.3 Application layer

18.2.3.1 AL service selection

Table 262 specifies the AL service selection within IEC 61158-5-21.

Table 262 – CP 17/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, symbols, abbreviations, and conventions	Partial	If applicable
4	Concepts	YES	—
5	Data type ASE	YES	—
6	Communication model specification	YES	—

18.2.3.2 AL protocol selection

Table 263 specifies the AL protocol selection within IEC 61158-6-21.

Table 263 – CP 17/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, symbols, abbreviations, and conventions	Partial	If applicable
4	FAL syntax description	YES	—
5	Transfer Syntax	YES	—
6	FAL protocol state machines	YES	—
7	AP context state machine	YES	—
8	FAL service protocol machine	YES	—
9	AR protocol machine	YES	—
10	DLL mapping protocol machine	YES	—

18.2.4 Performance indicator selection

18.2.4.1 Performance indicator overview

Table 264 shows the performance indicators overview of CP 17/1.

Table 264 – CP 17/1: PI overview

Performance indicator	Applicable	Constraints
Delivery Time	YES	None
Number of end stations	YES	None
Basic network topology	YES	None
Number of switches between end stations	Not practically limited by the protocol	RAPIEnet nodes are 2-port switches
Throughput RTE	YES	None
Non-RTE bandwidth	YES	None
Time synchronization accuracy	YES	None
Non time-based synchronization accuracy	No	None
Redundancy recovery time	YES	None

18.2.4.2 Performance indicator dependencies

18.2.4.2.1 Performance indicator dependency matrix

Table 265 shows the dependencies between performance indicators for CP 17/1.

Table 265 – CP 17/1: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy	Redundancy recovery time
Delivery time		Yes	NO	Yes	NO	NO	NO
Number of end stations	YES		NO	NO	NO	NO	NO
Basic network topology	NO	NO		NO	NO	NO	YES
Throughput RTE	NO	NO	NO		YES	NO	NO
Non-RTE bandwidth	NO	NO	NO	YES		NO	NO
Time synchronization accuracy	NO	YES	NO	NO	NO		NO
Redundancy recovery time	NO	YES	YES	YES	NO	NO	

18.2.4.2.2   Delivery time

The delivery time for communication between two RTE end stations can be calculated by Formula (89).

$$T_{DELAY} = T_{SND} + T_{PKT} + T_{CPD} + \sum_{i=0}^{N} T_{NLD\_i} + T_{RCV} \tag{89}$$

where

T_{DELAY}	is the delivery time in microseconds;
T_{SND}	is the sender stack traversal time including Phy and MAC in microseconds;
T_{PKT}	is the packet transmit time in microseconds, see Formula (90);
T_{CPD}	is the cable propagation delay time in microseconds, see formula (91);
T_{NLD_i}	is the node latency delay time of node i in microseconds, see formula (92);
T_{RCV}	is the receiver stack traversal time including Phy and MAC in microseconds;
N	is the number of nodes between sending and receiving end-stations.

The packet transmit time T_{PKT} can be calculated by Formula (90).

$$T_{PKT} = \frac{(APDUsize + POsize) \times 8}{LDR} \tag{90}$$

where

T_{PKT}	is the packet transmit time in microseconds;
$APDUsize$	is the size of the application protocol data unit in octets;
LDR	is the link data rate in bit per seconds;
$POsize$	is the size of the protocol overhead in octets.

The cable propagation delay time T_{CPD} can be calculated by Formula (91).

$$T_{CPD} = T_{CPD/M} \times L_{TC} \tag{91}$$

where

T_{CPD}	is the cable propagation delay time in microseconds;
$T_{\text{CPD/M}}$	is the cable propagation delay in nanoseconds per meter (depending on the characteristics of the selected cable);
L_{TC}	is the total cable length in meter.

The node latency delay time $T_{\text{NLD\_i}}$ can be calculated by Formula (92).

$$T_{NLD\_i} = T_{NPD\_i} + T_{PKT\_i} + \sum_{j=0}^{M} T_{TX\_PKT\_ij} \tag{92}$$

where

$T_{\text{NLD\_i}}$	is the node latency delay time of node i in microseconds;
$T_{\text{NPD\_i}}$	is the node propagation delay time of node i in microseconds;
$T_{\text{PKT\_i}}$	is the packet transmit time of node i in microseconds, see Formula (90);
$T_{\text{TX\_PKT\_ij}}$	is the packet transmit time of packet j in microseconds in the port transmit queue of node i in front on of this packet (depending on APDU size of node i) , see Formula (90);
M	is the number of packets in the port transmit queue of node i in front on of this packet.

18.2.4.2.3   Number of end stations

The maximum number of the end stations shall be 256.

18.2.4.2.4   Basic network topology

Basic network topology shall be a ring or a linear topology.

18.2.4.2.5   Redundancy recovery time

Redundancy recovery time of Media redundancy requires ring topology.

The traffic load in the ring shall be less than 90 %.

In case of copper media, the redundancy recovery time for communication between any two end stations is less than 160 ms (100 Mbit/s), 10 ms (1 000 Mbit/s).

In case of fiber optic media, the redundancy recovery time for communication between any two end stations is less than 8 ms (100 Mbit/s), 4 ms (1 000 Mbit/s).

18.2.4.2.6   Throughput RTE

Throughput RTE depends on the link data rate and protocol overhead. Throughput RTE for one direction of a CP 17/1 link operating can be calculated on the basis of Formula (93).

$$Throughput\_RTE = APDUsize \times (NF_{RTE/S} \le NF_{E/S\_MAX}) \tag{93}$$

where

$APDUsize$	is the size of the application protocol data unit in octets;
$NF_{RTE/S}$	is the number of frames allowed to be sent per second for one RTE end station;
NF_{E/S_MAX}	is the maximum number of frames allowed to be sent per second for one end station, see Formula (94).

The maximum number of frames allowed to be sent per second for one end station NF_{E/S_MAX} can be calculated by Formula (94).

$$NF_{E/S\_MAX} = \frac{LDR}{(APDUsize + POsize) \times 8} \tag{94}$$

where

LDR	is the link data rate in mega bit per seconds;
$APDUsize$	is the size of the application protocol data unit in octets;
$POsize$	is the size of the protocol overhead in octets.

18.2.4.2.7   Non-RTE bandwidth

The time not occupied by RTE communication can be used for non-RTE communication. Non-RTE bandwidth can be calculated as shown below.

18.2.4.2.8   Relation between throughput RTE and non-RTE bandwidth

The total link bandwidth is limited by the end station throughput, which is the same as the end station maximum packet rate. The total link bandwidth is therefore a sum of end station RTE and non-RTE packet rates and can be calculated using Formula (95).

$$BW_{NRTE} = \frac{NF_{E/S\_MAX} - NF_{RTE/S}}{NF_{E/S\_MAX}} \times 100\% \tag{95}$$

where

BW_{NRTE}	is the non-RTE bandwidth, in %.;
NF_{E/S_MAX}	is the maximum number of frames allowed to be sent per second for one end station;
$NF_{RTE/S}$	is the number of frames allowed to be sent per second for one RTE end station.

18.2.4.3   Consistent set of performance indicators

Parameters used for the calculation of Table 266 are shown in Table 267. All these parameters are the result of the described scenario and the related calculations of performance indicators.

Table 266 – Consistent set of PIs small size automation system

Performance indicator	Value	Constraints
Delivery Time	110 μs to 4 100 μs	Processing time is 10 μs, no failure at 100 Mbit/s (full-duplex)
	22 μs to 240 μs	Processing time is 10 μs no failure at 1 000 Mbit/s (full-duplex)
Number of end stations	256	–
Number of switches between end stations	0	RAPIEnet nodes are 2-port switches
Throughput RTE	0 octets/s to 5,55 x 10^6 octets/s	100 Mbit/s (full-duplex)
	0 octets/s to 5,55 x 10^7 octets/s	1 000 Mbit/s (full-duplex)
Non-RTE bandwidth	0 % to 100 %	—
Time synchronization accuracy	< 10 μs	—
Redundancy recovery time	n.a.	Linear topology
	< 160 ms	Ring topology (100BASE-TX)
	< 8 ms	Ring topology (100BASE-FX)
	< 10 ms	Ring topology (1000BASE-TX)
	< 4 ms	Ring topology (1000BASE-FX)

Table 267 – Parameters for Calculation of Consistent set of PIs

Parameter	Definition	Value
T_{SND}	Sender stack traversal time including Phy and MAC	Depends on the selected hardware platform and the embedded software implementation
T_{RCV}	Receiver stack traversal time including Phy and MAC	Depends on the selected hardware platform and the embedded software implementation
APDUsize	Size of the application protocol data	32 octets
LDR	Link Data Rate	100 Mbit/s
		1 000 Mbit/s
POsize	Size of the protocol overhead	40 octets
$T_{CPD/M}$	Cable propagation delay (depending on the characteristics of the selected cable)	5 ns/m
L_{TC}	Total cable length	100 m
T_{NPD}	Node propagation delay time	10 μs 100 Mbit/s
		0,5 μs 1 000 Mbit/s
N	Number of nodes between sending and receiving end-stations	Minimum: 0
		Maximum: 254

19 Communication Profile Family 18 (SafetyNET p[16]) – RTE communication profiles

19.1 General overview

Communication Profile Family 18 defines profiles based on IEC 61158-3-22, IEC 61158-4-22, IEC 61158-5-22 and IEC 61158-6-22.

In this document, the following communication profiles are specified for CPF 18.

– Profile 18/1

  This profile defines protocol and service selection for devices which utilize the communication model real time frame line (RTFL).

– Profile 18/2

  This profile defines protocol and service selection for devices which utilize the communication model real time frame network (RTFN).

19.2 Profile 18/1

19.2.1 Physical layer

The physical layer shall be based on standard Ethernet hardware according to ISO/IEC/IEEE 8802-3.

CP 18/1 devices shall use a data rate of 100 Mbit/s and full-duplex transmission mode. A combination of full-duplex and 100Base-TX with auto crossover function (wire, 2 twisted pairs) should be used.

When using cables, they shall be rated Cat5e or better, and shielded in an appropriate way (FTP, STP or SFTP) depending upon EMC constraints.

19.2.2 Data link layer

Data link layer is described in IEC 61158-3-22 and IEC 61158-4-22. Table 268 specifies the use of the services included in this profile. Table 269 specifies the use of the protocol included in this profile.

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[16] SafetyNET p is a trade name of the Pilz GmbH & Co. KG. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trade name holder or any of its products. Compliance to this profile does not require use of the trade name SafetyNET p. Use of the trade name SafetyNET p requires permission of the trade name holder.

Table 268 – CP 18/1: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Data-link layer services and concepts	—	—
4.1	Operating principle	YES	—
4.2	Communication models	—	—
4.2.1	Overview	YES	—
4.2.2	RTFL device reference model	YES	—
4.2.3	RTFN device reference model	NO	—
4.3	Topology	—	—
4.3.1	RTFL topology	YES	—
4.3.2	RTFN topology	NO	—
4.4	Addressing	—	—
4.4.1	Overview	YES	—
4.4.2	RTFL device addressing	YES	—
4.4.3	RTFN device addressing	NO	—
4.5	Gateway	YES	—
4.6	Interaction models	—	—
4.6.1	Overview	YES	—
4.6.2	Producer-consumer	YES	—
4.6.3	Publisher-subscriber	NO	—
4.7	Synchronization concept	YES	—
5	Communication services	—	—
5.1	Overview	Partial	Only services selected by this CP
5.2	Communication management services	—	—
5.2.1	Overview	YES	—
5.2.2	RTFL-network verification	—	—
5.2.2.1	DL-Network verification service (NV)	YES	—
5.2.2.2	DL-RTFN scan network read service (RTFNSNR)	NO	—
5.2.3	Communication management	—	—
5.2.3.1	DL-RTFN connection establishment service (RTFNCE)	NO	—
5.2.3.2	DL-RTFN connection release service (RTFNCR)	NO	—
5.2.3.3	DL-RTFL control service (RTFLCTL)	YES	—
5.2.3.4	DL-RTFL configuration service (RTFLCFG)	YES	—
5.2.3.5	DL-Read configuration data service (RDCD)	YES	—
5.2.3.6	DL-RTFL configuration service 2 (RTFLCFG2)	YES	—
5.2.3.7	DL-Read configuration data service 2 (RDCD2)	YES	—
5.3	Cyclic data channel service (CDC)	YES	—
5.4	Message channel services (MSC)	YES	—
5.5	Time synchronization	—	—

Clause	Header	Presence	Constraints
5.5.1	DL-DelayMeasurement start service (DMS)	YES	—
5.5.2	DL-DelayMeasurement read service (DMR)	YES	—
5.5.3	DL-PCS configuration service (PCSC)	YES	—
5.5.4	DL-Sync master configuration service (SYNC_MC)	YES	—
5.5.5	DL-Sync start service (SYNC_START)	YES	—
5.5.6	DL-Sync stop service (SYNC_STOP)	YES	—
5.6	Media independent interface (MII) management services	YES	—

Table 269 – CP 18/1: DLL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Overview of the DL-protocol	—	—
4.1	Operating principle	YES	—
4.2	Communication model	—	—
4.2.1	Overview	YES	—
4.2.2	RTFL device reference model	YES	—
4.2.3	RTFN device reference model	NO	—
4.3	Topology	—	—
4.3.1	RTFL topology	YES	—
4.3.2	RTFN topology	NO	—
4.4	DLPDU processing	—	—
4.4.1	Communication model RTFL	YES	—
4.4.2	Communication model RTFN	NO	—
4.5	General communication mechanisms	YES	—
4.6	Gateway	YES	—
4.7	Interaction models	—	—
4.7.1	Overview	YES	—
4.7.2	Producer-consumer	YES	—
4.7.3	Publisher-subscriber	NO	—
5	DLPDU structure	—	—
5.1	Overview	YES	—
5.2	Data types and encoding rules	YES	—
5.3	DLPDU identification	YES	—
5.4	General DLPDU structure	—	—
5.4.1	Type 22 DLPDU inside an ISO/IEC/IEEE 8802-3 DLPDU	YES	—
5.4.2	Type 22 DLPDU inside a VLAN tagged ISO/IEC/IEEE 8802-3 DLPDU	NO	—
5.4.3	Type 22 DLPDU inside an UDP DLPDU	NO	—
5.4.3	Type 22 DLPDU structure	YES	—

Clause	Header	Presence	Constraints
5.5	Communication management DLPDUs	—	—
5.5.1	RTFL-network verification DLPDUs	YES	—
5.5.2	RTFN scan network DLPDUs	NO	—
5.5.3	Identification data	YES	—
5.5.4	RTFN connection management DLPDU	NO	—
5.5.5	ID data	NO	—
5.5.6	RTFL control DLPDU	YES	—
5.5.7	RTFL configuration DLPDU	YES	—
5.6	Cyclic data channel (CDC) DLPDUs	—	—
5.6.1	Cyclic data channel line (CDCL) DLPDU	YES	—
5.6.2	Cyclic data channel network (CDCN) DLPDU	NO	—
5.7	Cyclic data channel (CDC) DLPDU data	YES	—
5.8	Message channel (MSC) DLPDUs	—	—
5.8.1	Message channel line (MSCL) DLPDU	YES	—
5.8.2	Message channel network (MSCN) DLPDU	NO	—
5.9	Message channel DLPDU data – MSC message transfer protocol (MSC-MTP)	YES	—
5.10	Time synchronization	YES	—
6	Telegram timing and DLPDU handling	—	—
6.1	Communication mechanism	—	—
6.1.1	Communication model RTFL	YES	—
6.1.2	Communication model RTFN	NO	—
6.2	Device synchronization	—	—
6.2.1	Communication model RTFL – precise clock synchronization	YES	—
6.2.2	Communication model RTFN	NO	—
7	Type 22 protocol machines	—	—
7.1	RTFL device protocol machines	YES	—
7.2	RTFN device protocol machines	NO	—
7.3	Message channel – message transfer protocol (MSC-MTP)	YES	—

19.2.3 Application layer

Application layer is described in IEC 61158-5-22 and IEC 61158-6-22. Table 270 specifies the use of the services included in this profile. Table 271 specifies the use of the protocol included in this profile.

Table 270 – CP 18/1: AL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Concepts	—	—
4.1	Common concepts	YES	—
4.2	Type specific concepts	—	—
4.2.1	Operating principle	YES	—
4.2.2	Communication model overview	—	—
4.2.2.1	Overview	YES	—
4.2.2.2	Communication model RTFL	YES	—
4.2.2.3	Communication model RTFN	NO	—
4.2.3	Application layer element description	YES	—
4.2.4	Producer-consumer interaction	YES	—
4.2.5	Device reference models	—	—
4.2.5.1	RTFL device reference model	YES	—
4.2.5.2	RTFN device reference model	NO	—
5	Data type ASE	YES	—
6	Communication model specification	—	—
6.1	Application service elements (ASEs)	—	—
6.1.1	CeS ASE	YES	—
6.1.2	ISO/IEC/IEEE 8802-3 DLPDU communication ASE	YES	—
6.1.3	Management ASE	YES	—
6.2	Application relationships (ARs)	—	—
6.2.1	Overview	YES	—
6.2.2	Point-to-point network-scheduled unconfirmed producer-consumer AREP	YES	—
6.2.3	Point-to-multipoint network-scheduled unconfirmed producer-consumer AREP	YES	—
6.2.4	Point-to-point network-scheduled confirmed client/server AREP	YES	—
6.2.5	Point-to-point user-triggered confirmed client/server AREP	NO	—
6.2.6	AR classes	Partial	According to the present ARs
6.2.7	FAL services by AREP class	Partial	According to the present ARs
6.2.8	Permitted FAL services by AREP role	Partial	According to the present ARs

Table 271 – CP 18/1: AL protocol selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Application layer protocol specification	—	—
4.1	Operating principle	YES	—
4.2	Device reference models	—	—
4.2.1	RTFL device reference model	YES	—
4.2.2	RTFN device reference model	NO	—
4.3	Application layer structure	YES	—
5	FAL syntax description	YES	—
6	FAL protocol state machines	YES	—
7	AP-context state machine	YES	—
8	FAL service protocol machine (FSPM)	YES	—
9	Application layer state machine (ALSM)	YES	—
10	DLL mapping protocol machine (DMPM)	YES	—

19.2.4 Performance indicator selection

19.2.4.1 Performance indicator overview

Table 272 gives an overview of the performance indicator usage.

Table 272 – CP 18/1: PI overview

Performance indicator	Applicable	Constraints
Delivery time	YES	None
Number of RTE end-stations	YES	None
Basic network topology	YES	Hierarchical star and linear topology
Number of switches between RTE end-stations	YES	For highest performance usage of switches shall be omitted
Throughput RTE	YES	None
Non-RTE bandwidth	YES	None
Time synchronization accuracy	YES	None
Non-time-based synchronization accuracy	NO	—
Redundancy recovery time	NO	—

19.2.4.2 Performance indicator dependencies

Table 273 specifies the dependencies of the performance indicators (row) from the performance indicators (column).

Table 273 – CP 18/1: PI dependency matrix

Dependent PI	Influencing PI						
	Delivery time	Number of end-stations	Basic network topology	Number of switches between RTE end-stations	Throughput RTE	Non-RTE bandwidth	Time synchronization accuracy
Delivery time		YES 19.2.4.5	YES 19.2.4.6	YES 19.2.4.7	YES 19.2.4.8	NO	NO
Number of end-stations	NO		NO	NO	NO	NO	YES 19.2.4.9
Basic network topology	NO	NO		YES 19.2.4.10	NO	NO	YES 19.2.4.11
Number of switches between RTE end-stations	NO	NO	YES 19.2.4.10		NO	NO	YES 19.2.4.13
Throughput RTE	NO	NO	NO	NO		YES 19.2.4.14	NO
Non-RTE bandwidth	NO	NO	NO	NO	YES 19.2.4.14		NO
Time synchronization accuracy	NO	YES 19.2.4.9	YES 19.2.4.11	YES 19.2.4.13	NO	NO	

19.2.4.3 Delivery time calculation

The performance indicator delivery time for a linear topology and a star topology can be calculated by Formula (96).

$$t_D = t_{cyc} + t_{STsrc} + t_{data} + t_{CD} * (l_F + l_B) + \sum_{i=1}^{NoDoF}\left(t_{pd}(i) + t_{SW}(i)\right) + \sum_{i=1}^{NoDoB}\left(t_{pd}(i) + t_{SW}(i)\right) + t_{ST\sin k} \quad (96)$$

where

t_D is the delivery time;

t_{cyc} is the cycle time of the communication system ($t_{cycle} \geq t_{data}$);

t_{STsrc} is the stack traversal time including data-link layer and physical layer of the source;

t_{data} is the time to transmit all Real-time DLPDU for one cycle;

t_{CD} is the cable delay (4,5 ns/m to 5 ns/m);

l_F is the distance along the cable in meters which is passed by the packed from source to last device of the logical line;

l_B is the distance along the cable in meters which is passed by the packed from last device of the logical line to sink;

t_{pd} is the propagation delay of a device in forward or backward direction;

t_{SW} is the delay caused by switching procedure;

NoDoF is the number of succeeding devices on forward direction from the source to the last device of the logical line;

NoDoB is the number of succeeding devices on backward direction from the last device of the logical line to the sink;

t_{STsink} is the stack traversal time including data-link layer and physical layer of the sink.

NOTE 1   In the case of a linear topology the time factor t_{SW} has the value 0.

NOTE 2   The distance in each direction is affected by the number of switching devices within the network topology.

19.2.4.4   Basic network topology

The basic network topologies supported by this profile are hierarchical star or linear topology. It is highly recommended to use linear topology to reach highest performance. For both basic network topologies this profile establishes a logical line topology by appropriate addressing within devices. For detailed information, refer to IEC 61158-4-22.

19.2.4.5   Delivery time dependency on number of end-stations

The number of end-stations typically influences the amount of data, thus the time to transmit the data DLPDU as well as the sum of propagation delays. Furthermore the number of devices on forward and backward direction is influenced and hence the delivery time as described in Formula (96).

19.2.4.6   Delivery time dependency on basic network topology

The delivery time depends on the amount of signal propagation delays within a network which are introduced by a given network topology. The network topology dependent parameters in terms of additional delay times are considered in Formula (96).

19.2.4.7   Delivery time dependency on number of switches between RTE end-stations

The delivery time depends on the amount of signal propagation delays within a network which are introduced by switches between RTE end-stations. The switch dependent parameters in terms of additional delay times are considered in Formula (96).

19.2.4.8   Delivery time dependency on throughput RTE

The delivery time depends on throughput RTE via data amount and cycle time. Throughput RTE can be adapted by changing the parameters data amount and cycle time, whereas the minimal reachable cycle time depends highly on the amount of data to be transferred. If throughput RTE is increased by increasing the amount of data transferred within one cycle, the delivery time is increased. An increase of throughput RTE by reducing the cycle time decreases the delivery time. Throughput RTE can be increased by an adequate adjustment of both parameters without influencing the delivery time as described in Formula (96).

19.2.4.9   Relation between number of end-stations and time synchronization accuracy

The number of end-stations influences the accuracy of time synchronization and vice versa.

19.2.4.10   Relation between basic network topology and number of switches between RTE end-stations

The usage of switches is restricted to hierarchical star topology.

19.2.4.11   Relation between basic network topology and time synchronization accuracy

The usage of switches (for example to build up a hierarchical star topology) reduces the reachable accuracy of time synchronization of devices.

19.2.4.12   Relation between number of end-stations and time synchronization accuracy

The number of end-stations influences the accuracy of time synchronization and vice versa.

19.2.4.13 Relation between number of switches between RTE end-stations and time synchronization accuracy

Accuracy of time synchronization is the maximum jitter between device clocks. The usage of switches reduces the reachable accuracy of time synchronization of devices.

19.2.4.14 Relation between throughput RTE and non-RTE bandwidth

The non-RTE bandwidth is the difference between overall bandwidth and the RTE throughput (RTE overhead included) hence both values influence each other.

19.3 Profile 18/2

19.3.1 Physical layer

The physical layer shall be based on standard Ethernet hardware according to ISO/IEC/IEEE 8802-3.

19.3.2 Data link layer

Data link layer is described in IEC 61158-3-22 and IEC 61158-4-22. Table 274 specifies the use of the services included in this profile. Table 275 specifies the use of the protocol included in this profile.

Table 274 – CP 18/2: DLL service selection

Clause	Header	Presence	Constraints
1	Scope	YES	—
2	Normative references	YES	—
3	Terms, definitions, abbreviations and conventions	Partial	If applicable
4	Data-link layer services and concepts	—	—
4.1	Operating principle	YES	—
4.2	Communication models	—	—
4.2.1	Overview	YES	—
4.2.2	RTFL device reference model	NO	—
4.2.3	RTFN device reference model	YES	—
4.3	Topology	—	—
4.3.1	RTFL topology	NO	—
4.3.2	RTFN topology	YES	—
4.4	Addressing	—	—
4.4.1	Overview	YES	—
4.4.2	RTFL device addressing	NO	—
4.4.3	RTFN device addressing	YES	—
4.5	Gateway	YES	—
4.6	Interaction models	—	—
4.6.1	Overview	YES	—
4.6.2	Producer-consumer	NO	—
4.6.3	Publisher-subscriber	YES	—
4.7	Synchronization concept	YES	—
5	Communication services	—	—
5.1	Overview	Partial	Only services selected by this CP